GreenTech project
Mini-conference
2023/01/19

Agenda

- ❑ **Welcome and introduction**
- ❑ **Presentations**
  - ➔ Stakeholders mapping
  - ➔ Survey and interviews

    Received feedback on the purpose and design of training modules
  - ➔ Lessons learned: "Building blocks"

    by Pepijn van Willigenburg, The Hague University of Applied Sciences
  - ➔ Blueprint for 6 GreenTech training modules
- ❑ **Discussion**

Objectives

Context

Climate change and zero carbon transition

New knowledge required / a more complex energy system

Importance to train more versatile technicians, with a whole picture

Lack of qualified manpower (maintenance technicians)

Objectives

Breaking down the barriers between individual energy system training courses

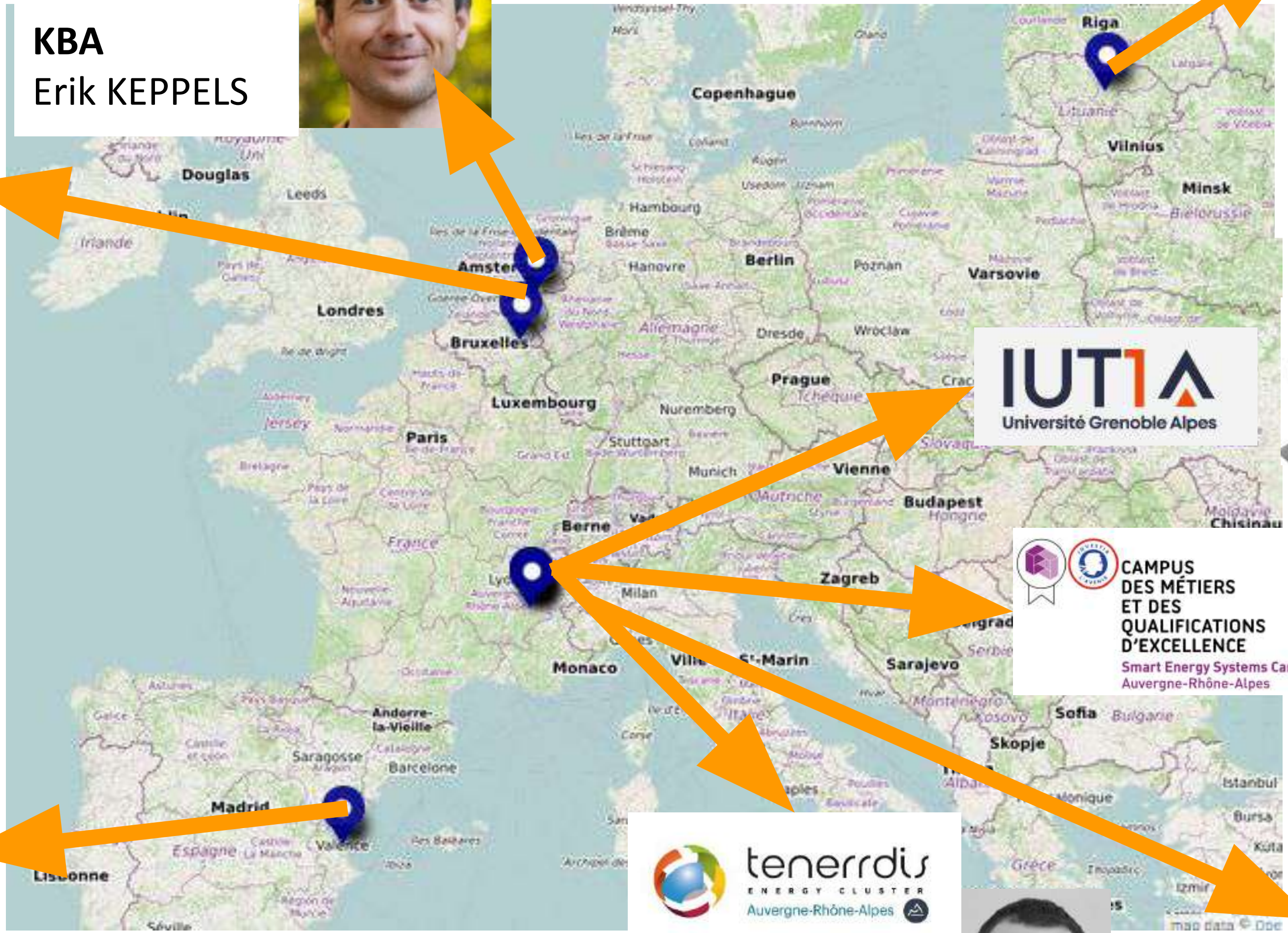
Create **training modules** for technicians dealing with the new energy mix

Partners

KBA
Erik KEPPELS

UCCL
Peter VAN HOUT

Panevezio Kolegija
Jovita KAZIUKONYTE
Remigijus KALIASAS



IUT1 - UGA
Cyril PICARD

Campus Smart Energy Systems
Michel BUREL
Anabelle MORICEAU

CENTRO DE FORMACIÓN PROFESIONAL

XABEC
Gregorio BLANCO SAEZ

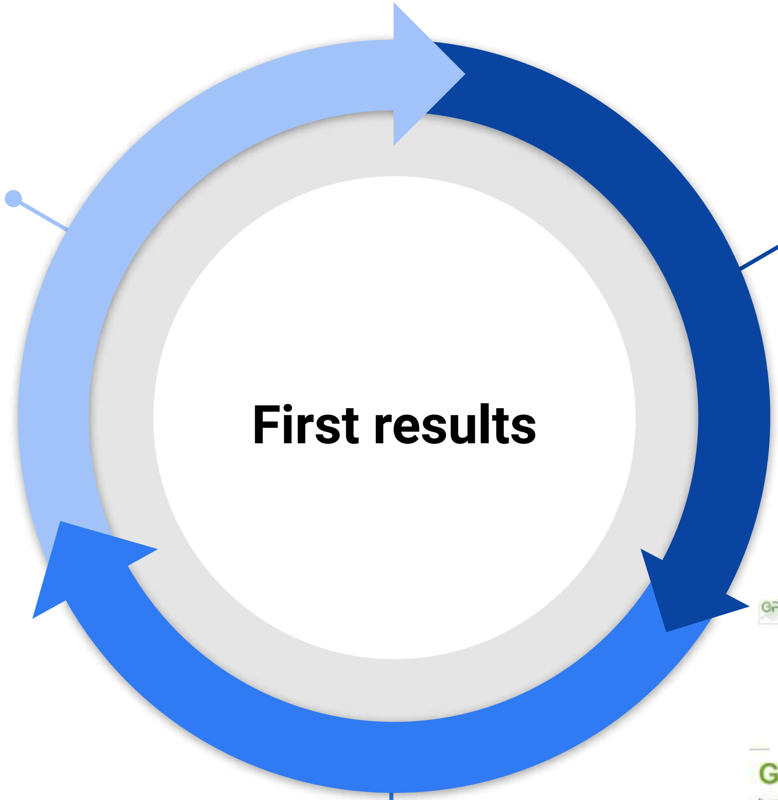
TENERRDIS
Philippe CHUZEL

GIP FIPAG
Nadia GONTHIER

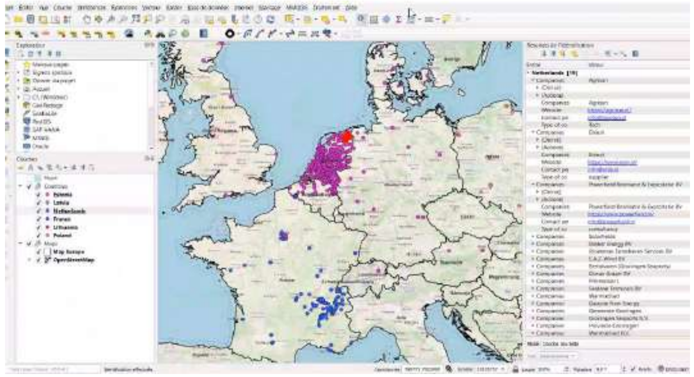
Erasmus+

Expected results : upstream phase

Erasmus + project : the results must benefit the greatest number of people



STAKEHOLDERS MAPPING
(in progress)



SURVEY AND INTERVIEWS

WEBSITE

https://greentech-erasmus.eu/

Erasmus+

Expected results : training modules

Erasmus + project : the results must benefit the greatest number of people

M0 — M1 — M2 — M3 — M4 — M5 — MOOC

M0	M1	M2	M3	M4	M5	MOOC
INTRO	SOLAR ENERGY	WIND ENERGY	NETWORK MANAGEMENT STORAGE	H2 GREEN PRODUCTION	USAGE	LEARNING

Mapping of stakeholders

Objective

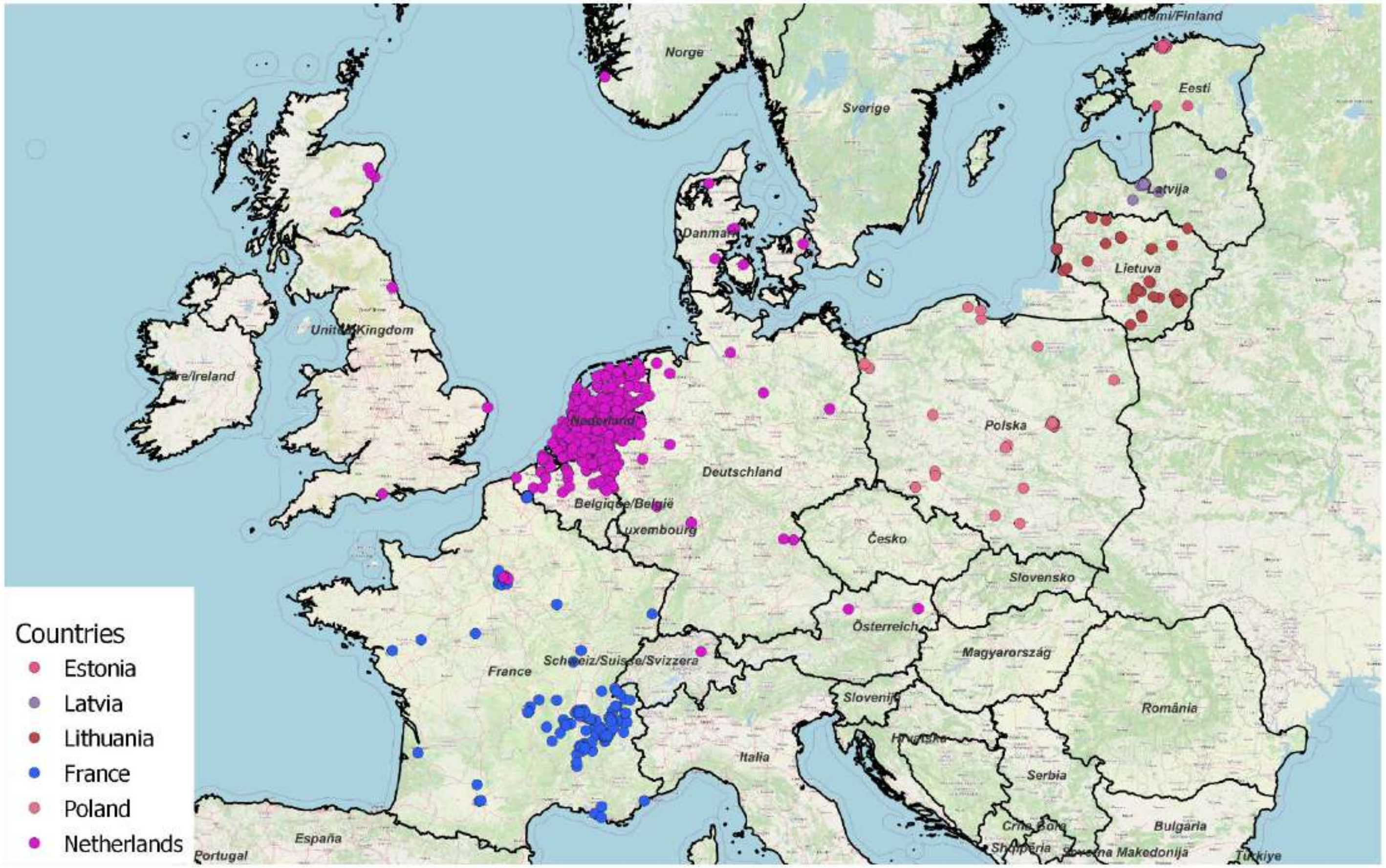
- **To run the survey (input)**
- **To announce the results of the project – dissemination / knowledge sharing (output)**

- **For a better knowledge of the different energy sectors and stakeholders within**
  - Who are we doing this for?
  - Is there already a multi-energy approach?
  - Not meant to be a complete list of all stakeholders (too much!)

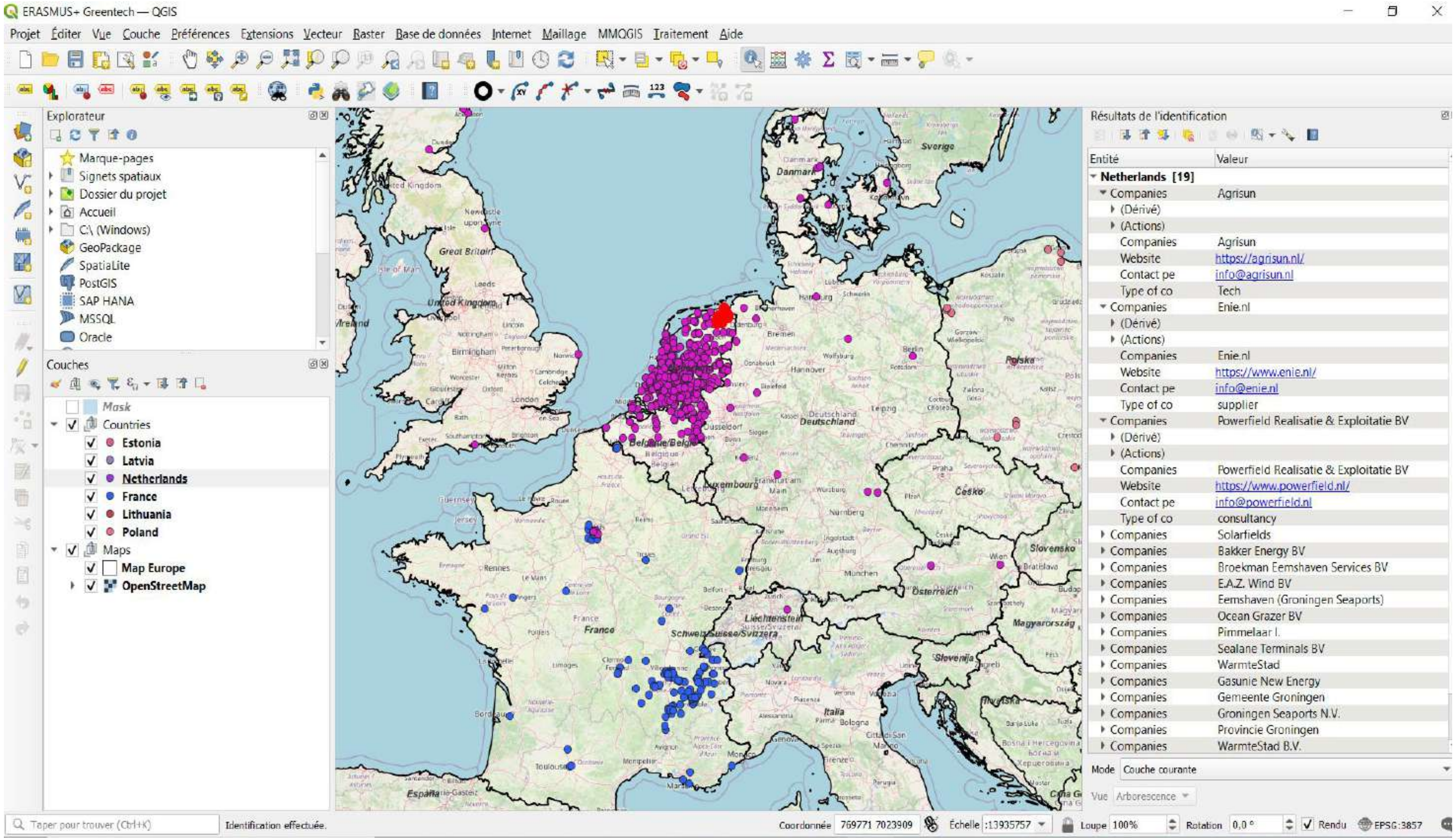
- **As a database for future interconnections (we need to work together for energy transition to succeed)**
  - During and after project
  - For this project and for others

Mapping (work in progress)

Mapping Erasmus+ Greentech



Mapping (will be added to greentech-erasmus.eu)



Survey and interviews

KBA Nijmegen

- **KBA Nijmegen**
- **Research institute in the field of education and labour market**
- **Studies mainly for Dutch ministry of education ‘OCW’, for NRO and educational funds**
- **www.kbanijmegen.nl**

- **Erik Keppels, senior researcher**
- **Leader for survey and interviews**
- **e.keppels@kbanijmegen.nl**

Objectives of survey and interviews

- **Correct focus → link between education and companies/countries**
  - Energy transition strategy of the EU-country
  - Needs of industrial world
  - Take into account the differences between EU-countries
  - Which skills, which level, which professionals are modules best suited for?

- **Adaptation and finetuning the content of the modules**
  - Presenting blueprint (first ideas)
  - Getting feedback (thank you for the feedback! See paragraph 3.3 in the report)

- **Findings in report that was sent with the invitation**

Response

Table 2 – Type of company/institution that responded to the survey

Type	Response
Companies *installing/repairing or maintaining* solar panels, heat pumps, windmills etc.	27%
Education: colleges or university institutions	17%
Companies offering advice in the field of renewable energy	10%
Companies *designing and engineering* solar panels, heat pumps, windmills etc.	9%
Companies *manufacturing* solar panels, heat pumps, windmills etc.	7%
Energy providers	5%
R&D institutions in the field of renewable energies	4%
Energy network/grid/storage companies	2%
Government agencies or public authorities (local, regional, or national)	1%
Other	19%
	N=122

- **Plus 44 interviews conducted with companies and educational institutions in 5 countries**

Priorities for the energy transition strategy

- **Energy sources**
  - Low hanging fruit first (need to act fast!): SOLAR and WIND
  - Then hydro, geothermal, biomass, nuclear (dubious, both proponents and opponents!)

- **Technical developments**
  - Storage (battery & hydrogen H2)
  - Interconnections between energy sectors (gas/heat, gas/electricity, transport/stationary energy production etc.)

- **Other suggestions**
  - Local production and local storage (self-production and self-storage)
  - Using less energy, re-usage and circular economy
  - Awareness, education, bigger price difference between fossil fuels and renewable energy

Most important challenge to overcome

Table 4 – Most important type of challenge to overcome in order to accomplish the energy transition and to achieve the necessary carbon reduction

	Total
Governmental/visionary/strategical challenges	**48**
Labour/skills/human resources challenges	**23**
Technological challenges	**14**
Behavioural challenges	**10**
Financial challenges	**5**
Other	**2**
Total	**102**

- **Governmental/visionary/strategical challenges: we can do it if we really want to (Ukraine)**
  - But lots of hurdles left in execution: procedures, permits etc.
- **Labour challenges**
  - Shortage of technical staff/professionals
  - Need of proper training due to new technologies, interconnections, fast changing market

Skills and competences needed

Table 7 – Skills/competences that technical professionals are currently lacking (descending order of (fully) agree)

	(Fully) disagree	Neutral	(Fully) agree	**Total**
Practical skills/competences	14%	11%	75%	**N=91**
Theoretical skills/competences	17%	17%	67%	**N=90**
Soft skills (such as adaptability, communication)	28%	30%	42%	**N=88**

- **Challenge**
  - Need of practical and theoretical skills/competences
  - Due to new technologies, interconnections, fast changing market
  - What are the possibilities and how do we apply and interconnect?

Feedback on the modules

- **Suitable as an introduction course (which it is!)**
   - For all types of professionals and on all levels (as an introduction course!)

- **Usefulness in different EU-countries?**
   - Differences in education levels and training programs
   - Solution: universally applicable building blocks (more about this in next presentation!)

- **Be aware: training modules are only the start before real implementation**
   - Marketing, building into training programs, translation, finding teachers and maybe training facilities, willingness of companies to train their employees

- **Tips available material and links to relevant/similar projects**
   - Lots is happening! No one has overview!
   - List in report (see paragraph 3.4 in the report. By no means complete!)

ERASMUS+ project ‘DCT-REES’

Green Tech project meeting Jan 2023 - NL

The Hague University of Applied Sciences
Electrical and Electronics Engineering (TIS-Delft)
Researchroup ‘Energy in Transition’
P. van Willigenburg

Contents

- Introductions
- Introduction of ERASMUS+ programme
- Challenges in DCT-REES needs analysis
- Conceptual Solution: Notes
- Notes in more detail

Introductions

Pepijn van Willigenburg

- Management of Technology / Not EE
- Business Development Manager THUAS
- Project Manager mostly NL funded applied research projects since 2012 (energy)
- Initiator of project, supported by Prof Annick Dexters / KU Leuven
- Without prior experience first assistant coordinator, second half coordinator of the project

THE HAGUE UNIVERSITY OF APPLIED SCIENCES

Erasmus+

Introducting DCT-REES

DCT-REES

Direct Current Technologies – Renewable Energy Education and Skills development program in South-Africa

EU		South Africa
The Hague University of Applied Sciences		Cape Peninsula University of Technology
Delft University of Technology		Durban University of Technology
KU Leuven		Tshwane University of Technology
University College Leuven Limburg		Nelson Mandela University
RWTH Aachen		North-West University
Fachhoch Schule Aachen		University of Johannesburg
Technische Hochschule Cologne/Koln		University of South-Africa (distance learning)

THE HAGUE UNIVERSITY OF APPLIED SCIENCES

Introducting DCT-REES

DCT-REES

- The main aim of DCT-REES was to develop and implement a new educational programme on DC technologies for South African universities, in order to supply the country and its industry with adequately trained professionals it needs to overcome its challenges in the field of electrical engineering.

Introducting DCT-REES

DCT-REES sub-objective 1

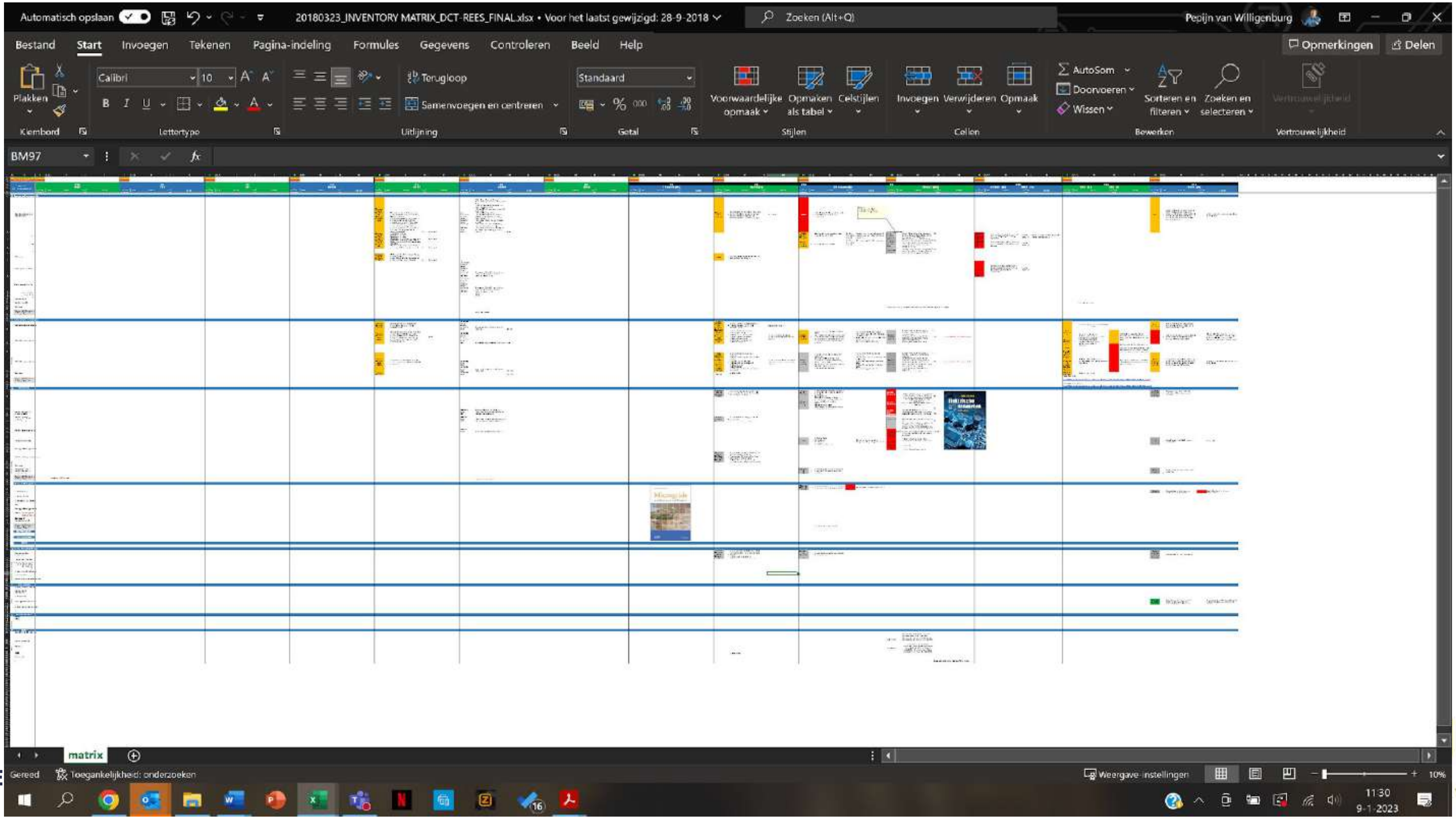
- To develop a new educational programme on DC for South Africa, containing a theory part, a lab practice part and a part for industry assignments and demonstrators, in order to address South Africa's energy (education) challenges.

1 semester, Power Electronics & DC courses

Challenges Needs Analysis

- All partners offer Bachelor programs
  - Most in 6, some in 7 or 8 semesters.
  - SA partners had an ‘Honors Program’
  - Electrical and/or Electronics Engineering
- All partners offered Power Electronics
  - But what levels, what learning objectives, what skills? In what year?
  - Skills & experience staff involved differed
- Student numbers in South-Africa higher
  - Students per teacher ratio..

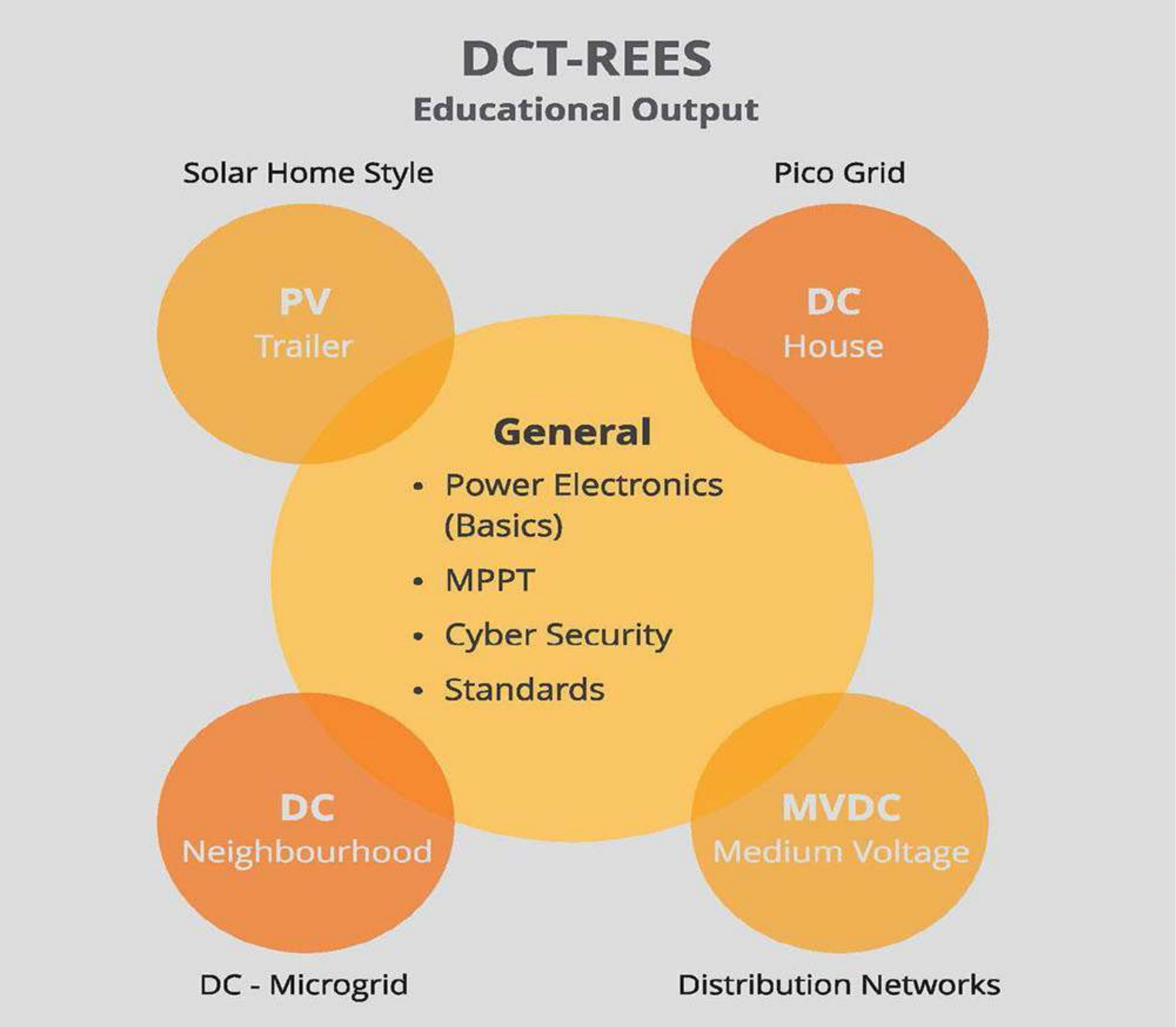
Challenges Needs Analysis



Conceptual Solution: Notes

- Concept Developed by Prof Annick Dexters
  - KU Leuven
- Summary: A NOTE in the DCT-REES context is a sub-set of educational material, to be used as a flexible building block to develop courses and programs. NOTES were constructed around 4 use cases, each representing a DC system or a sub-system. Some of the NOTES have been found to be relevant for more than 1 use case. They are labelled 'General'.

Conceptual Solution: Notes



KU LEUVEN

DCT-REES

Notes Concept in Detail

Prof.ir. Annick Dexters
KULeuven Technologiecampus Diepenbeek
annick.dexters@kuleuven.be
0496/69 23 53

Problem Statement

- The project partners have **difficulties in determining** on the one hand, **materials that the European partners should provide** and on the other hand **what the South African partners expect and need**.
  On the other hand the SA partners seem to have different, perhaps **more applied needs.**

- The **DCT-REES inventory matrix** shows that there are **not a lot of off-the-shelf courses or lab tutorials** on modern (latest in Power Electronics) DC-technology available. The knowledge of DC technology is **predominantly available in papers and research reports.**

NOTES: characteristics

These notes:

- **can be basic, advanced or for experienced users**
- are never more than 20 to 30 pages and answer to one main specific question. **The title of the note should be well-considered.**
- mention what you will learn with this note.
- mention predecessor and succession notes. What notes are required prior to fully understanding this note? In ‘note x’ a more complex situation / exemptions are dealt with.
- always refer to the sources used and sources interesting to consult if the reader needs more in depth information.
- mention the name(s) of the writer(s) & reviewer(s) + dates

Notes = RAW and VALIDATED knowledge

- Every partner is free to use them as a part of a course, to combine them to a course, as a basis of PPTs …

Which notes should be provided?

- This depends on the complexity and **voltage level of the part of the energy system we want to focus** on.
- Use cases should be identified with **increasing complexity** : basic, medium and advanced.
- **USE CASES**
  - PV trailer = Solar home style
  - DC NANOGRID = household
  - DC MICROGID can be as simple as a PV-installation or wind turbine coupled to the grid or as complex as an entity (building, neighbourhood, campus) with loads, storage, generation units that can be connected and disconnected to/from the main
  - (MVDC)
- For every use case a list of notes should be determined, necessary to help the student achieve the knowledge, skills and competences he/she needs to design, develop and implement that part of the grid where the use case focusses on.

Contact Information

To work together, partners agreed to use the Xdemia platform to share materials, free for academics

https://xdemia.com/space/dct-rees-public-space/about

- About the project

https://xdemia.com/space/dct-rees-public-space/documents

- Overview of all Notes developed
- Overview of video Lectures

https://xdemia.com/space/dct-rees-central

- Members only section, to work with Notes

Contact Information

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Module 1 SOLAR ENERGY

Where in the world can you find Panevezys University of Applied Sciences?

Module 1: Solar Energy

Result Title	**Module 1: Solar Energy**
Result Leading Organisation	PANKO
Result Participating Organisations	XABEC, UCLL, TENERRDIS

Result production start date	07/2022
Result production end date	07/2023
Result languages	English
Result media type	Online course theoretical & practical exercises

DESCRIPTIVE SHEET

Outcomes	Teaching / Learning Methods	Content	Prerequisites
Able assess ways of promotion of renewable energy technologies. Able to explain the design, efficiency and economic justification of solar cells. Able to explain peculiarities of electric power generation using solar photo elements, principles of their operation as well as area of their use. Able to explain principal operating of solar cells, their advantages and disadvantages, depending on various conditions. Able assess technologies for preparation of hot water using solar collectors. Able to explain technologies for heating of buildings using solar energy and possibilities for the use of them. Able assess critically the role of circular economy in sustainability progress.	Assignments, Experiential learning, Lecture	Politics of usage of solar energy Solar photoelements for generation of electric energy Solar thermal energy Photovoltaic thermal hybrid (PVT) solar collectors Circular economy in solar energy	Electrical engineering, Thermodynamics

Interview report

Interview was conducted in two ways: by phone and by e-mail. 14 participants were contacted, 3 of them answered the questions immediately. For others, questions were sent by e-mail. Responses were received from nine. Unfortunately, it should be mentioned that the interviewees' willingness to participate was small, although everyone emphasized the need for such a module but refused to comment further.

1. I represent…

An energy network/grid/storage company	2
A company designing and engineering solar panels, heat pumps, windmills, or other renewable energy devices/equipment	1
A college or university institution	5
A government agency or public authority (local, regional, or national)	4

All results are presented in Erik Keppels report survey and interviews concept

CONTENT

- **PV modules (system)**
  - Fabrication of PV modules
  - Series and parallel connections in PV modules
  - PV module parameters
  - Designing grid-connected PV systems
  - Designing stand alone PV systems
  - Installation on roof, on ground

- **Location issues**
  - The position of the Sun
  - Irradiance on a PV module
  - Direct and diffuse irradiance

- **Components of PV systems**
  - Maximum power point tracking
  - Power electronics
  - Batteries
  - Charge controllers
  - Cables

- **Solar thermal energy**
  - Solar thermal basics
  - Solar thermal heating
  - Components of ST system
  - Installation
- **PVT systems**
- Circular economy in solar energy (supplemented)

CONTENT SUGGESTIONS

- safety protocols and risk prevention (working with electricity and working at height for example), working with forklift (license), protection against over temperatures in thermal solar energy installations and protection for regular PV energy systems
- installation on more surfaces than roof and ground (for example on water) and the impact of the installation (ecology, heat stress)
- duration and degradation of PV panels; the importance of the quality of PV panels and DC cables and installation/connections
- calculation tools
- inverters, inverter technologies, oversizing
- integration batteries with energy management systems EMS (not only in module 5)
- application of direct current/voltage and smart grids (not only in module 5)
- installation: support structures including ballast plan, wiring techniques, direct current, fuse box reinforcement
- some argue to not include PVT systems (PVT needs support from another heat production system. PVT is not similar to PV but more to air conditioning and because the module is mainly about understanding the concept of systems it might be better to not include it or to just broadly mention it)

FEEDBACK REPORT

At the same time, pilot content of the module was sent to colleagues at UCLL, TENERRDIS and XABEC. Based on the useful comments of colleagues, the module will be adjusted and supplemented.

Module 2 - Wind Energy

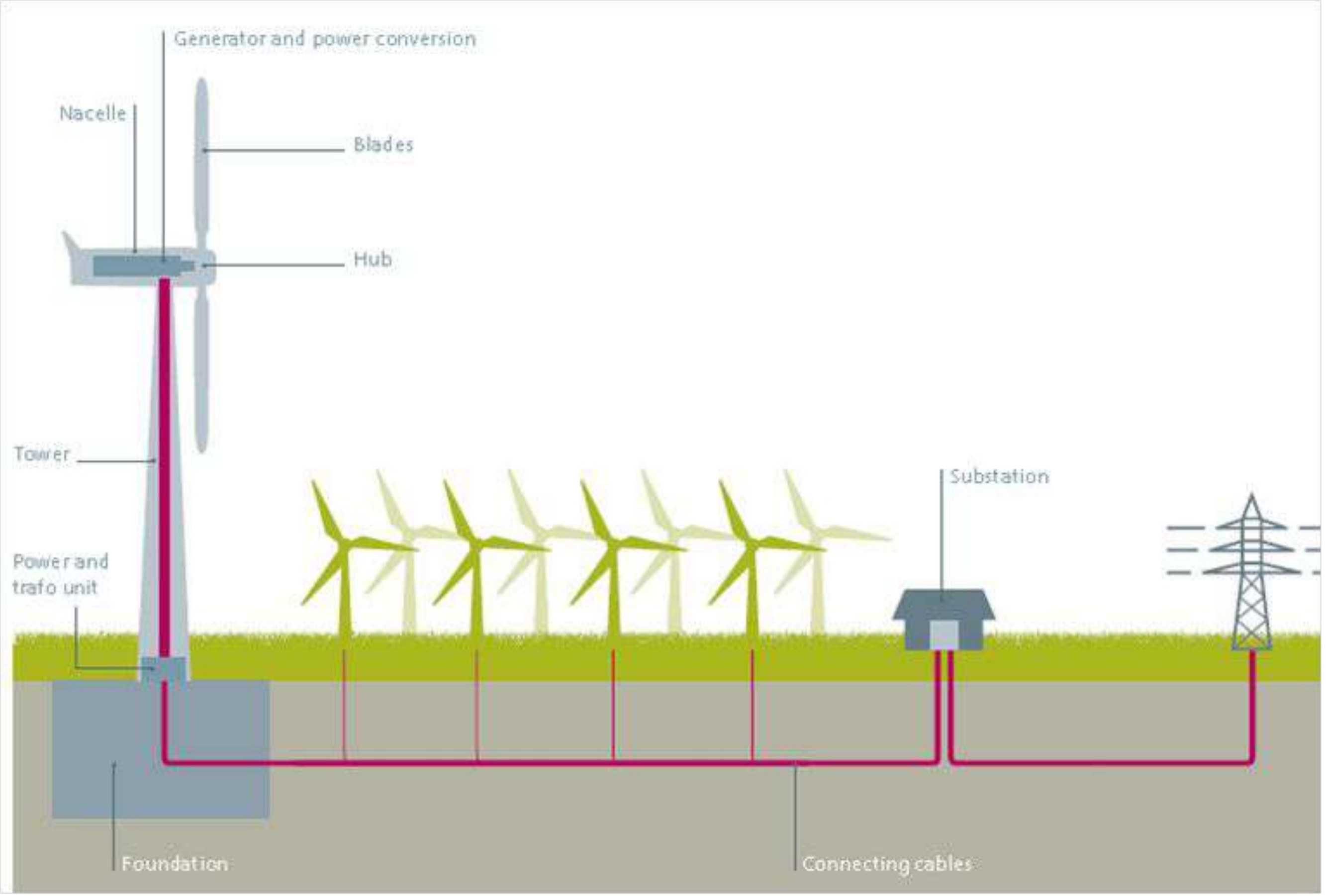
Team

Centro de Formación Profesional XABEC – Spain Valencia			
Name	**Profile**	**Role**	**Tasks**
Juan Carlos Morón	Telecommunication engineers	Teacher	Materials development
Jose Manuel Alegre	Architect	Teacher	Materials development
Gregorio Blanco	Bussiness Administration	Coordinator	Contents Development

Tenerrdis
Philippe Chuzel
Energy cluster France - Grenoble

Panko
Jovita Kaziukonytė Remigijus Kaliasas
University of Applied Sciences Lithuania -Panevėžio

Structure of the contents

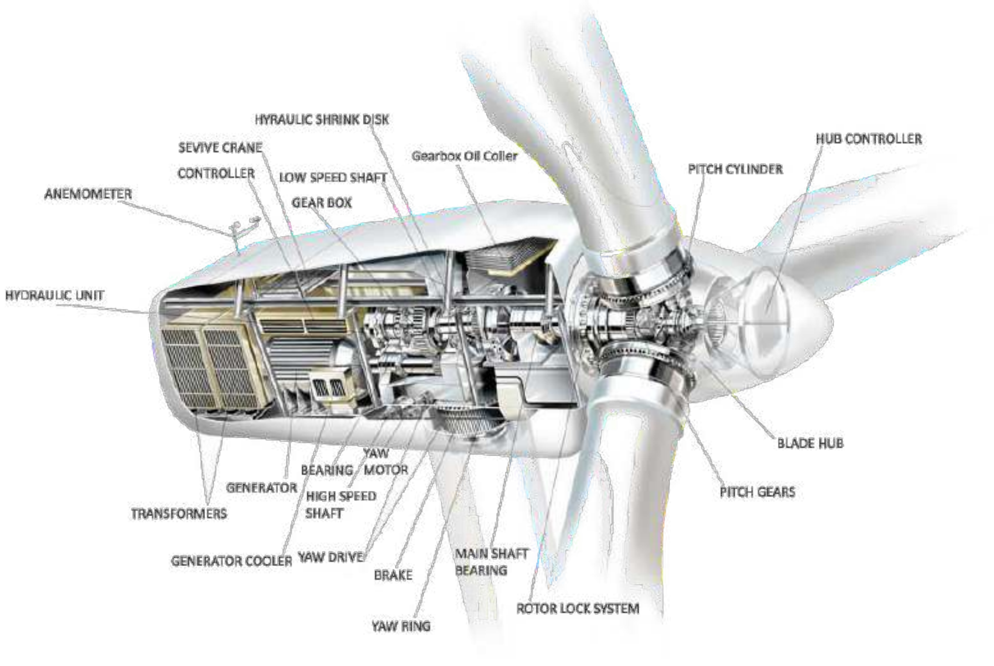


1. Context and background.
2. Components of a wind structure.
3. Description of a complete wind system:
   - Wind turbine
   - Infrastructure
   - Control system
   - Maintenance of wind turbines and their components.
4. Example of a wind farm design.
5. Return of investment.
6. Circular economy.

Wind Energy

Methodology

1. Contact with our VET students who are working in wind energy companies such us Acciona and Siemes Gamesa.
2. Maintenance operations from different companies.
3. Contact with teachers of renewable energy training for adults and tecnicians
4. Study of manuals used in technical studies,
5. Contact and presentations by companies in the renewable energy sector
6. Autonomous investigation
7. Wind Europe - https://windeurope.org/



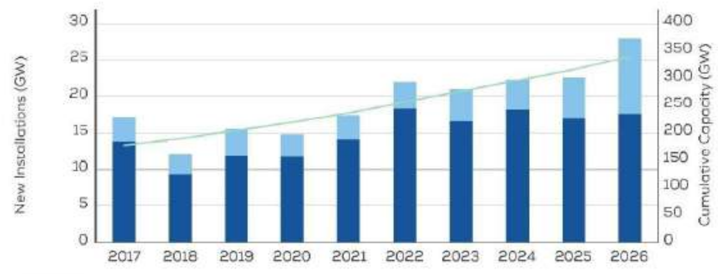
Wind Energy

Background

The countries that increased their wind power the most were, in this order, the United Kingdom, Sweden, Germany, Turkey and the Netherlands, according to data from the European Wind Energy Association (WindEurope). During that year, wind generated 437 TWh, enough to cover 15% of the electricity demand of the European Union (E.U.), of which 12.2% comes from offshore wind and 2.8% from land.“

Iberdrola

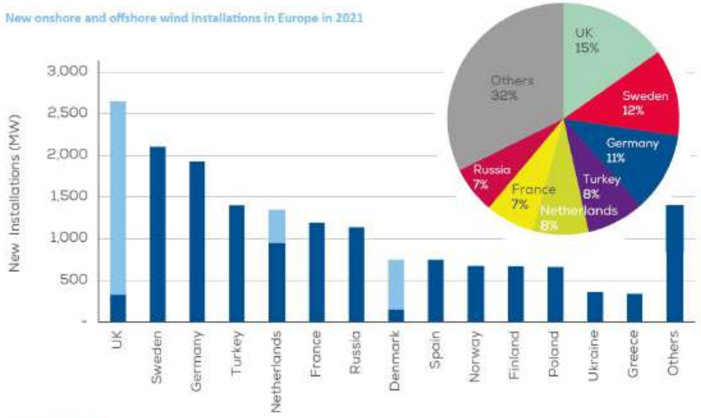
FIGURE 15
Expected new installations 2022-26 - Realistic Expectations Scenario



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Offshore	3.2	2.7	3.6	2.9	3.3	3.5	4.4	4.1	5.4	10.4
Onshore	13.9	9.4	11.9	11.8	14.0	18.3	16.6	18.1	17.0	17.6
Cumulative	177	189	204	219	236	256	276	296	315	341

Source: WindEurope

New onshore and offshore wind installations in Europe in 2021



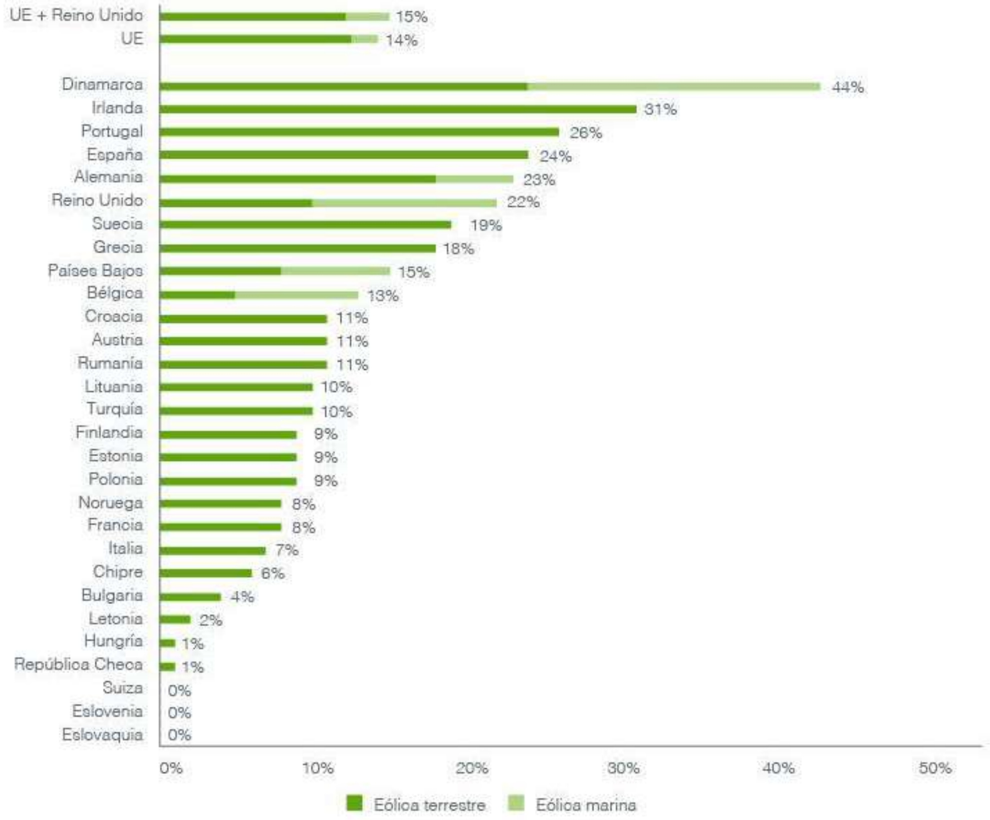
	UK	Sweden	Germany	Turkey	Netherlands	France	Russia	Denmark	Spain	Norway	Finland	Poland	Ukraine	Greece	Others
Offshore	2,317	-	-	-	392	-	-	605	-	4	-	-	-	-	-
Onshore	328	2,104	1,925	1,400	952	1,192	1,139	149	750	672	671	660	359	338	1,402
Total	2,645	2,104	1,925	1,400	1,344	1,192	1,139	754	750	676	671	660	359	338	1,402

Source: WindEurope

Wind Energy

Background

Percentage of the average annual demand of electricity covered by eolics - 2021



Fuente: WindEurope

In the 19th century, the first wind turbines would be designed, which would allow electricity to be brought to many rural areas. At the end of the century, the **Poul La Cour Askov** wind generator would be put into operation in Denmark, which would mark the beginning of modern wind energy.

Already in the 20th century, specifically in the 1970s, the oil crisis changed the world energy paradigm, placing emphasis on renewable energy for the first time. Wind energy returned to value and raised funding for its research and development.

In the 1980s, the first wind farm in Europe would be inaugurated in Greece, with a generating power of about 20kW. Later in the 1990s the first offshore wind farm would be created in Denmark with a capacity of up to 450 kW.

In the last 20 years, wind energy production has grown exponentially, designing high-power wind turbines and wind farms capable of covering the electrical needs of a large part of the population.

Wind Energy

What Companies and technicians Demand

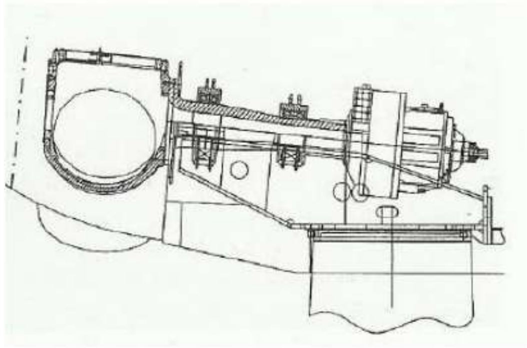
Level 4 technical profiles: **Electromechanical** or Electrical Maintenance and level 5: **Mechatronics** or Renewable Energies

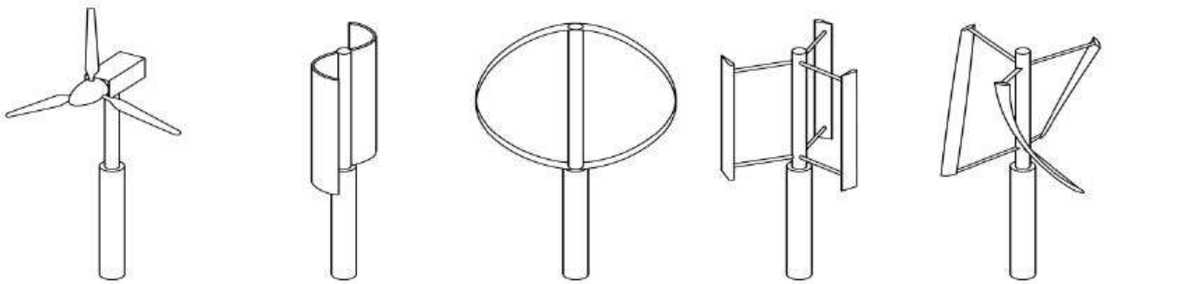
- Predictive maintenance technicians. Periodic maintenance oil changes and maintenance of hydraulic groups
- Corrective maintenance technicians: Inspection, review, maintenance and repair of electrical, mechanical and hydraulic parts of wind turbines
- Large corrective technicians: Change of large components
- Commissioning technician

AND

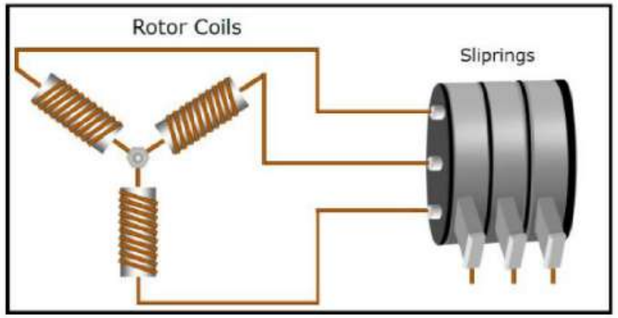
Passion for renewable energy
Willing to work in an international context
Committed to safety at work

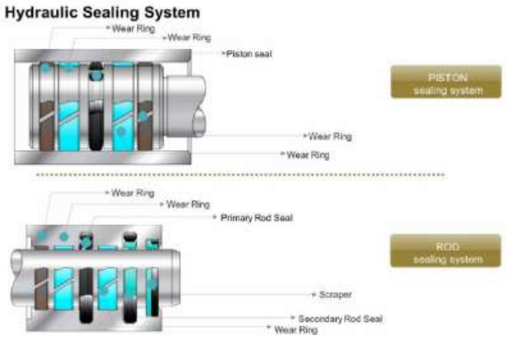
Components of a wind structure.

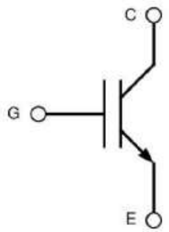


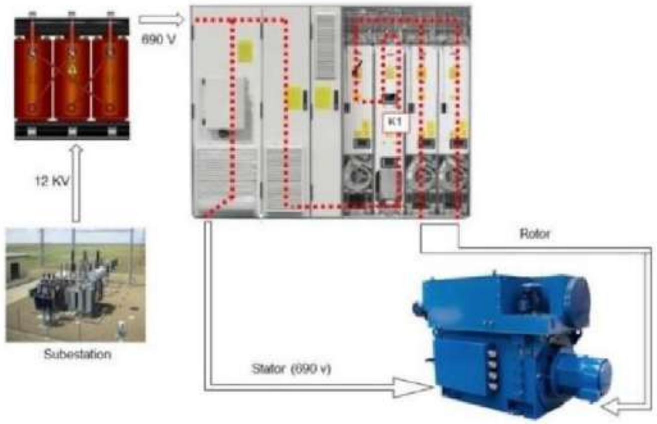


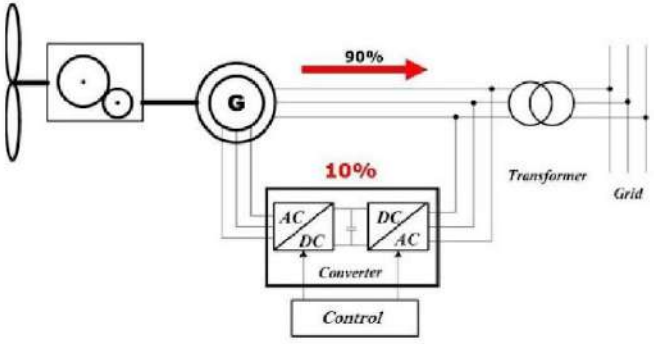
Description of a complete wind system:











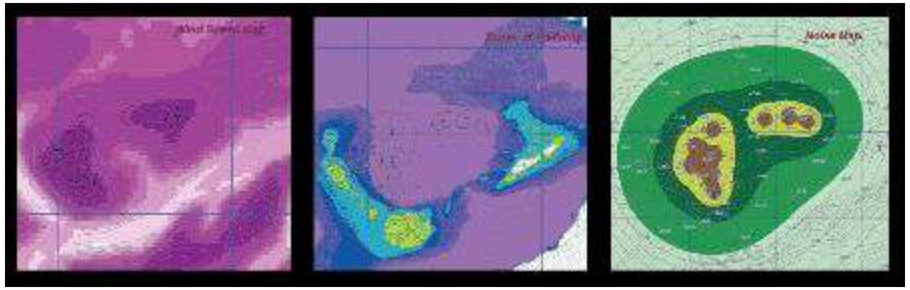
Wind Energy

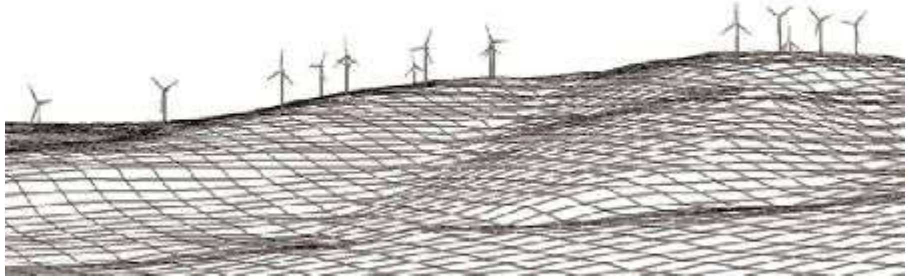
Maintenance of wind turbines and their components – Check List

- auditory inspection of blades
- check wind speed
- check room temperature
- electrical overspeed test.
- test ogs
- record date of last inspection lifeline
- hoist visual inspection
- Nacelle fire extinguisher review (contractual). record date of last inspection
- visual inspection of the welding in the tower access door frame (every 2 years)
- visual inspection of the exterior and interior painting of the first section (every 2 years)
- *check that the safety stickers are correctly positi*oned
- ground area fire extinguisher review (contractual). record date of last inspection
- wardrobe floor review
- …..

Wind Energy

Example of a wind farm design.

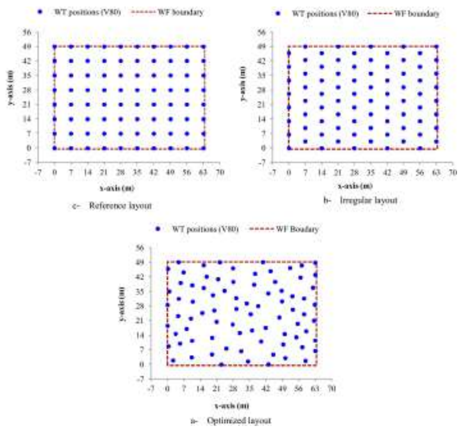


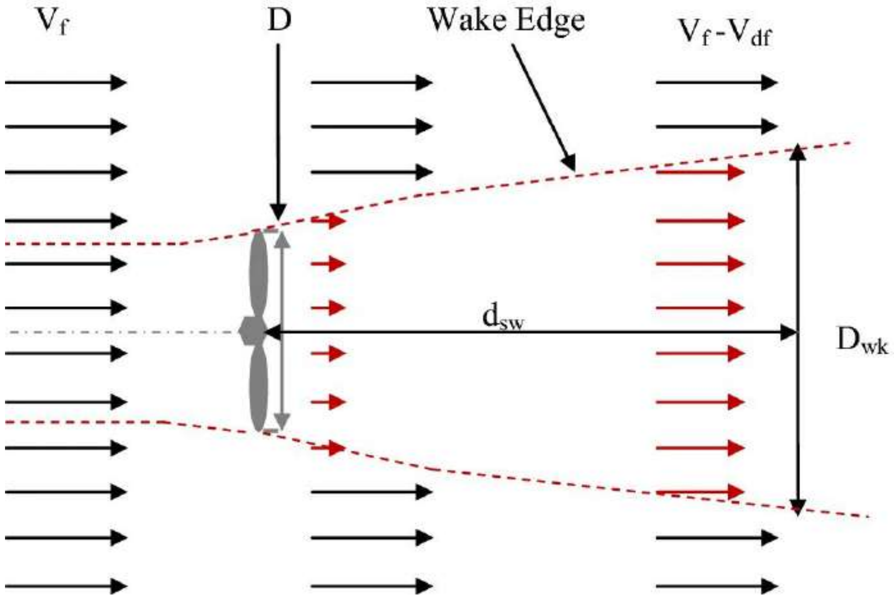


Calculation of the electrical needs to be covered.

The SCADA system

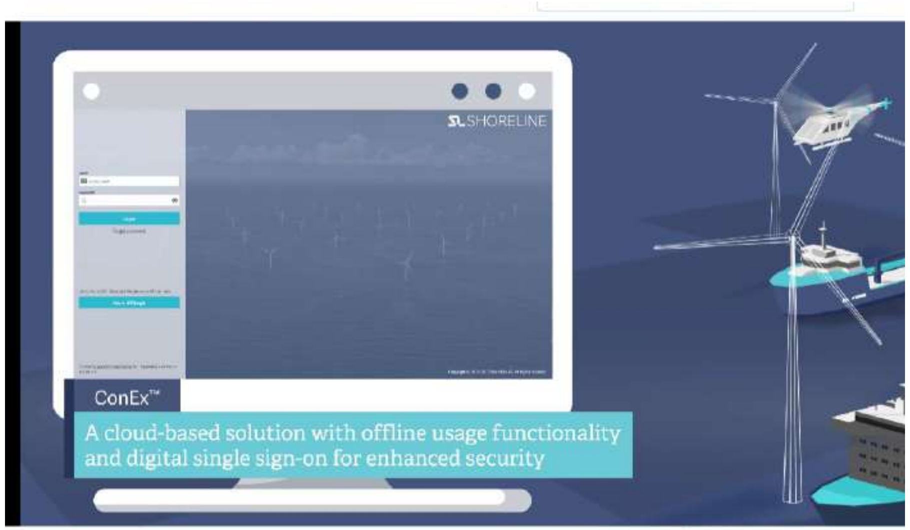
Visual impact



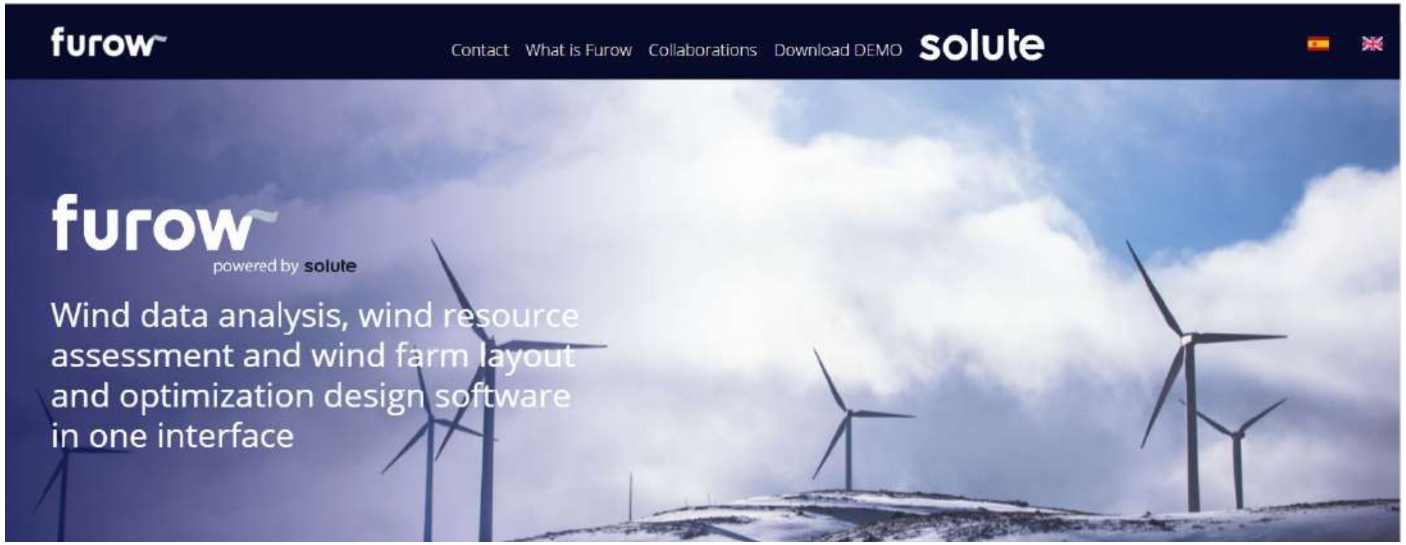


Wind Energy

Digital Tools



windPRO



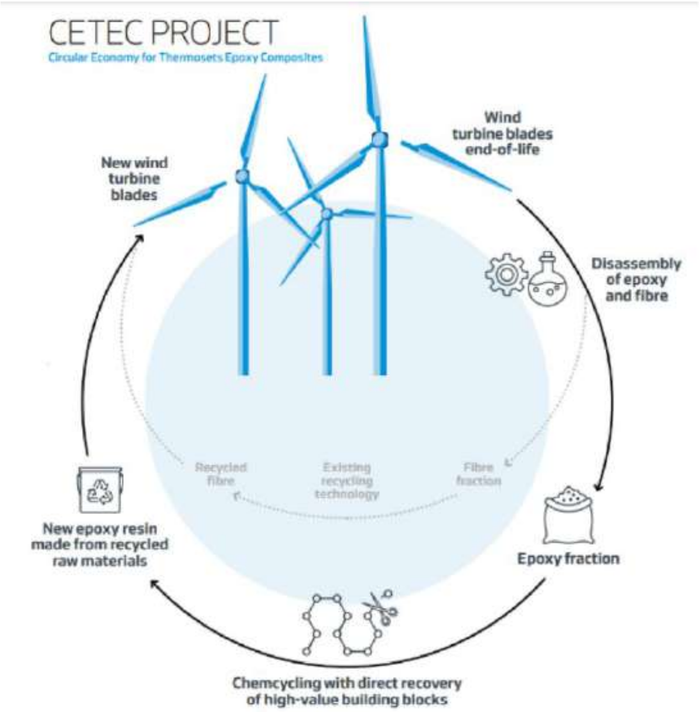
Wind Energy

Protection Equipment:

- Electrical Risk.
- Risk of falling from height
- Risk of chemical contacts
- Noise Protection
- Falling Objects/shocks and blows
- Mechanical Risks

Wind Energy

Circular Economy



The wind industry is committed to achieve the full recyclability of our turbines in line with the EU's Circular Economy Action Plan and the ambitions of the EU Green Deal.

The industry commits to re-use, recycle or recover 100% of decommissioned blades.

The wind industry will develop an industry roadmap further detailing the steps required to accelerate wind turbine blade circularity. This roadmap will focus on four workstreams:

- implementing the landfill ban,
- achieving full recyclability of existing blades in the future,
- making future blades fully circular and
- engaging with other sectors.

Course organisation and outcomes

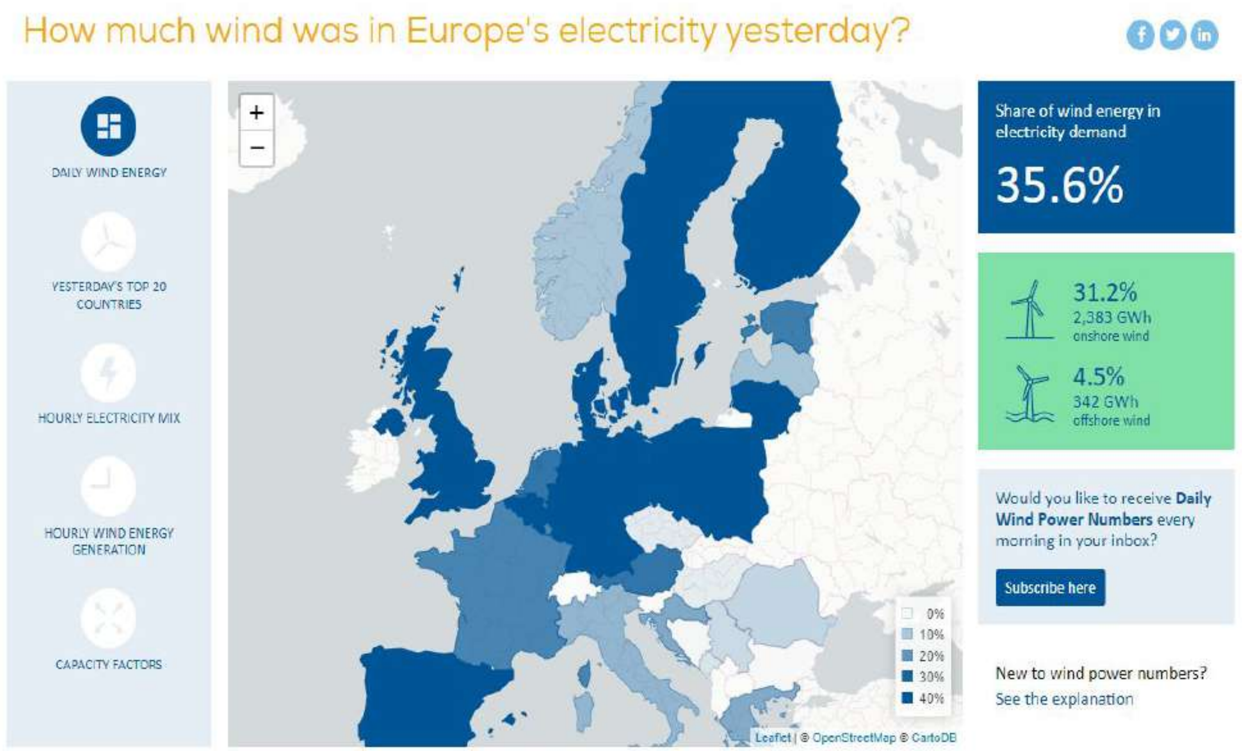
Theoretical Outcomes:

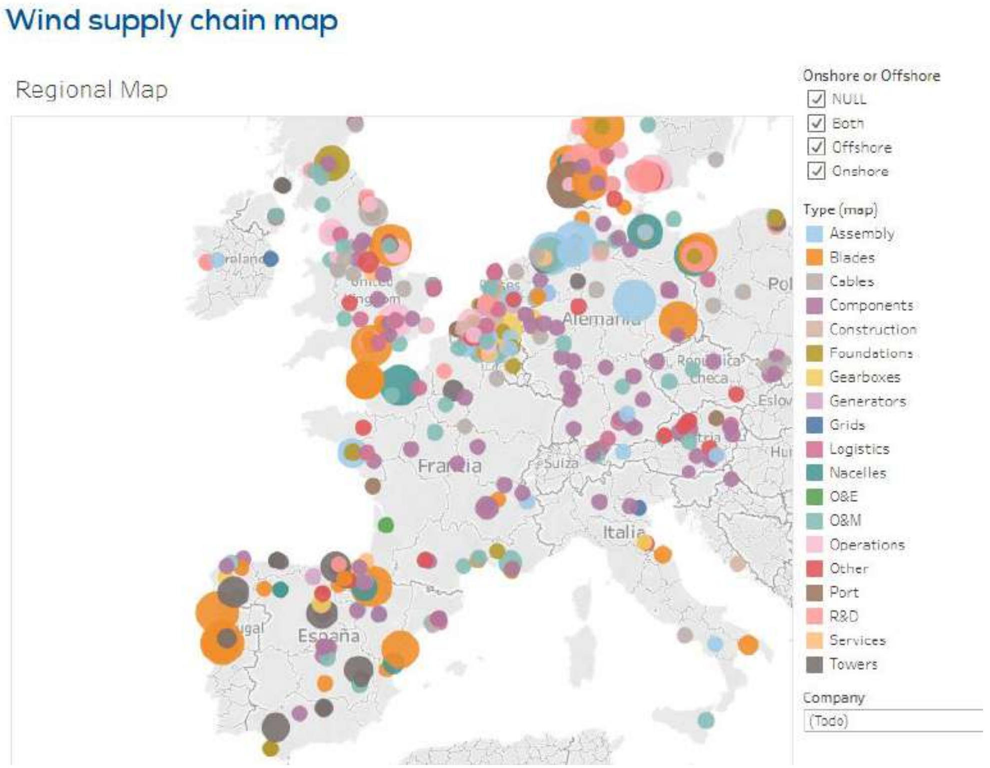
Origins of wind energy and current situation
Description of the components of a wind installation
Knowledge of digital tools for measuring consumption and calculating facilities
Knowledge of remote work tools.
Knowledge of the necessary protective equipment to work in a wind farm
Circular economy of wind farms

Practical Outcomes

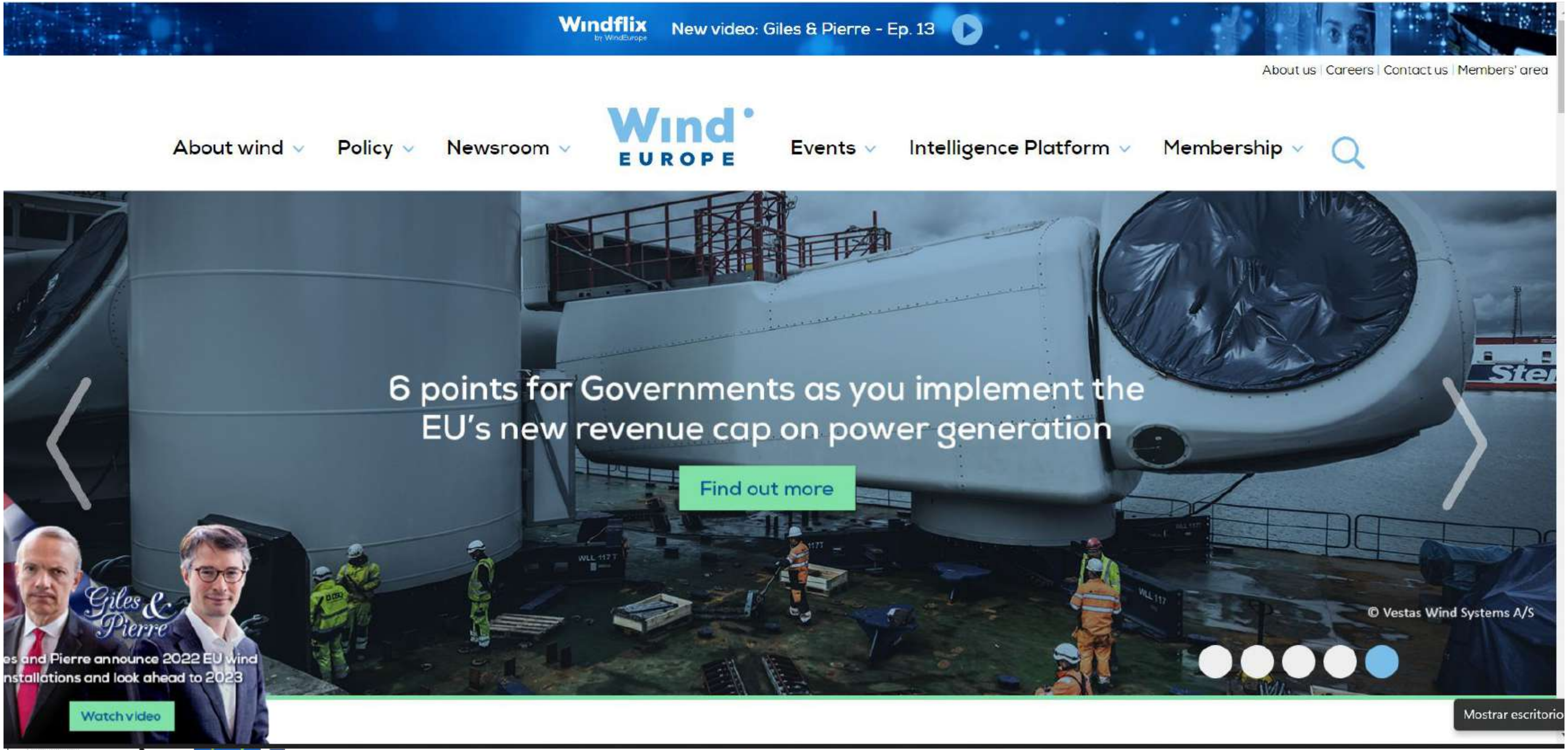
Sizing of a wind installation
Knowledge of maintenance operations

Wind Energy – Some Figures





Wind Energy – One website to visit



Module 3 – Network management and storage

UCLL - University of Applied Sciences

UCLL HOGESCHOOL

RESEARCH & EXPERTISE

15 500 students
1 750 employees

300 Researchers

16 Associate degree (EQL 5)
18 Professional bachelor (EQL 6)

6 Campuses

8 Expertise centres

Sustainable Resources

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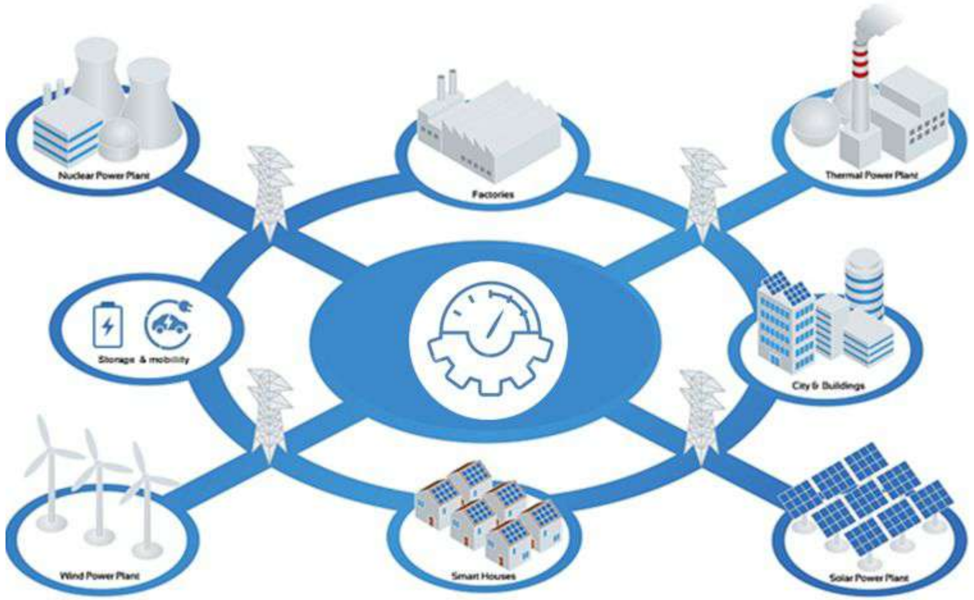
Module 3 – Network Management & Storage

- Energy Conversion : link between generation, storage and usage

- Energy Storage Concepts

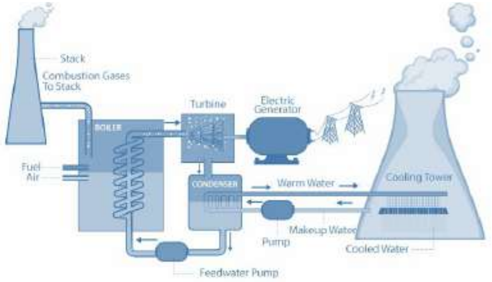


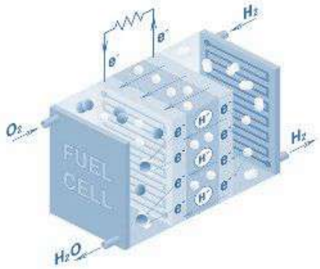
- Energy Management

Module 3 – Network Management & Storage

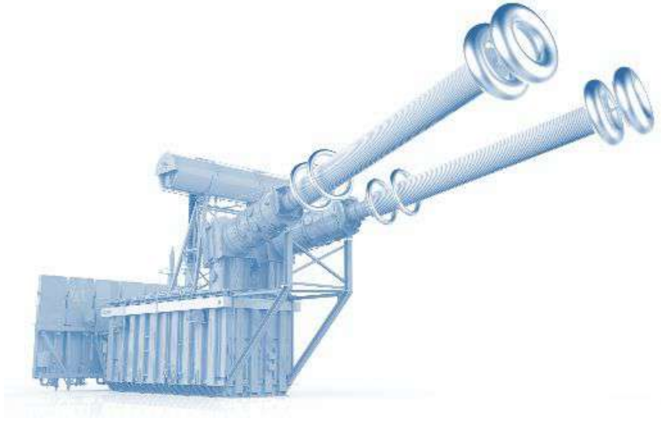
Energy Conversion : link between generation, storage and usage

- Energy production
  - Classic Production Plants : thermal, nuclear, CCGT, CHP
  - Renewables : PV, wind, hydropower, H2 fuel cells





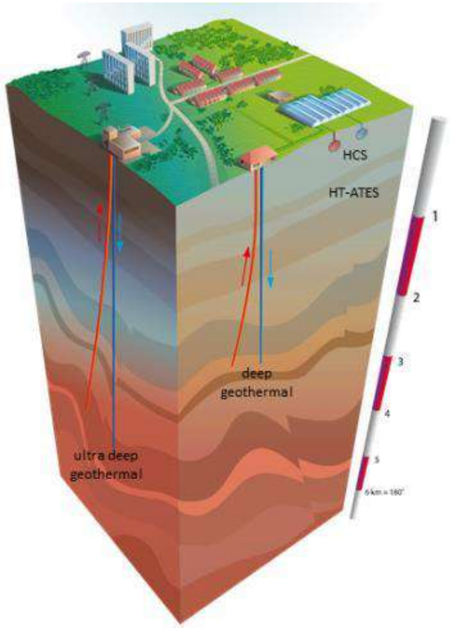
- Transmission & Distribution
  - Energy transport from power plants to consumers
  - AC & DC grids
  - transformers-convertors
  - Voltage levels, protection



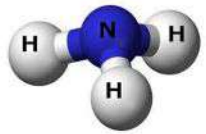
Module 3 – Network Management & Storage

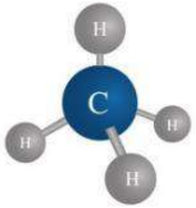
Energy Storage Concepts

- Electrical batteries : Li-ion, other chemicals,
  V2G vehicle to grid
- Water : pumped hydro



- Mechanical : fly wheels
  compressed air
- Heat : geo-thermal, networks
- Molecules : H2, NH3, CH4,
  CCS, CCU, clathrate hydrogen

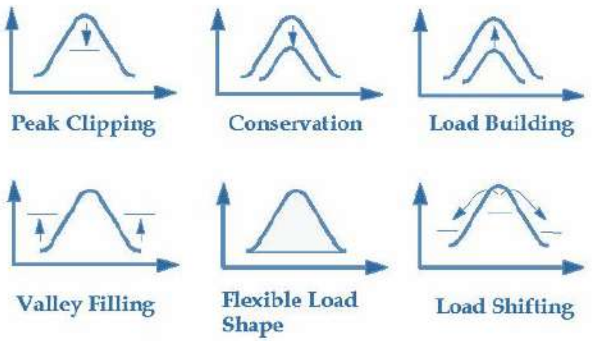




Module 3 – Network Management & Storage

Energy Management - EMS

- Power grid, Smartgrid, µGrid
- DSM Demand side mgmt
- SCADA
- VPP Virtual powerplants
- Local energy communities
- Smartmetering
- Home appliances
- Pricing €/kWh vs €/kW



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Module 4 – Hydrogen green production


Credit: McPphy

CAMPUS DES MÉTIERS ET DES QUALIFICATIONS D'EXCELLENCE
Smart Energy Systems Campus Auvergne-Rhône-Alpes

académie Grenoble – GIP FIPAG – VOS COMPÉTENCES POUR DEMAIN

KBA Nijmegen

PANEVĖŽIO KOLEGIJA

UCLL HOGESCHOOL

xabec CENTRO DE FORMACIÓN PROFESIONAL

UGA Université Grenoble Alpes

tenerrdis ENERGY CLUSTER Auvergne-Rhône-Alpes

Cont

7.6 PROJECT RESULT – MODULE 4 – HYDROGEN GREEN PRODUCTION

Result Title	**Module 4: Hydrogen green production**
Result Leading Organisation	IU1/UGA
Result Participating Organisations	IU1/UGA and Tenerrdis

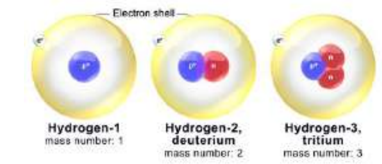
Result Description (including: needs analysis, target groups, elements of innovation, expected impact and transferability potential)

The objective of this project result is to achieve the creation of a teaching module providing theoretical courses and practical training on the processes used in the hydrogen sector with a focus on its production. The module deals with the production of hydrogen as an energy vector by means of electrolysis with electricity supplied from renewable low carbon energy sources. Given the current context of climate change, the production of hydrogen from fossil sources is not a long-term solution although it is currently the main source of hydrogen (i.e. ammonia process). The module will present the different ways to produce hydrogen and will then focus on electrolysis only as it is the main industrial solution which is envisioned as a key valorisation technique for wind and solar energy storage in the context of the low carbon transition.

This module will describe all the required stages to produce compressed hydrogen from water by means of electrolysis. The module will give the theoretical basis needed to understand the working process of the different equipment used in a hydrogen production unit. The module will introduce the different technologies at use in these equipment and associated features and constraints. The formation will be based on courses and exercises cessions as well as practices, which are essential to be at ease with the usage of this equipment. In addition, the innovative nature of the module is to be constructed as a learning situation to develop valuable competences.

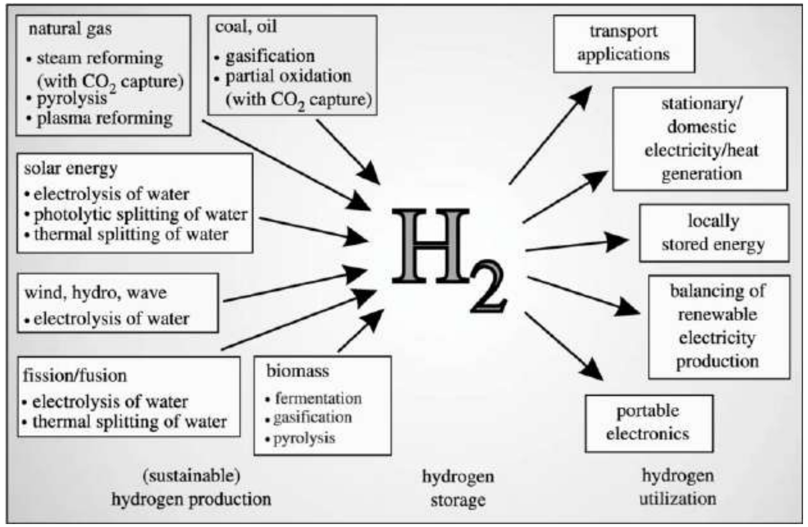
Such a hydrogen refuelling station or a hydrogen production plant comprise three main stages, namely water purification (deionization), water electrolysis, and hydrogen compression for a future usage (described in the M5 module). To understand these three stages (purification, electrolysis, compression) basic theoretical knowledge are required in

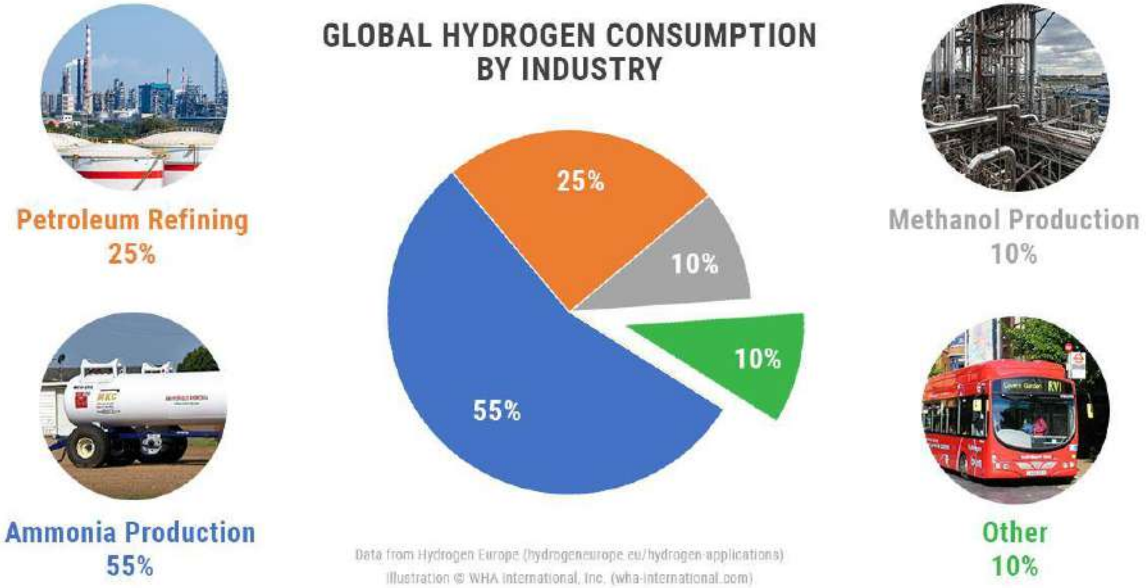
Content

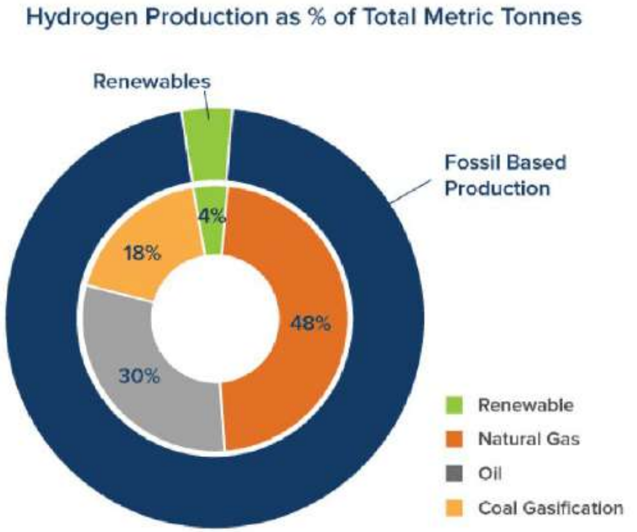


Hydrogen: a brief overview

- Hydrogen properties
- From its discovery to current usages
- Overview of possible roles in the future energy mix
- Green H_2 production: focus on the main steps







…2500 TWh of H_2 in 2050 for Europe

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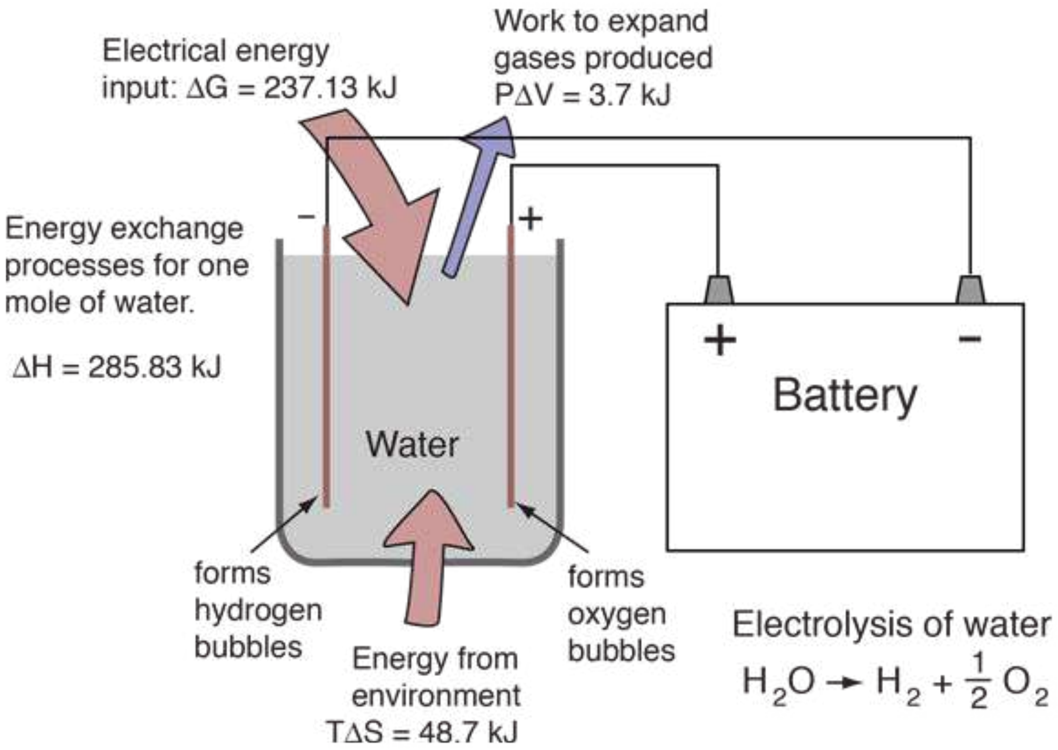
From water to H_2: some theoretical tools

- **Osmosis and reverse osmosis :**
  Thermodynamics of mixing and transport in porous media

- **Electrolysis**
  Electrochemistry, thermodynamics and kinetics limitation

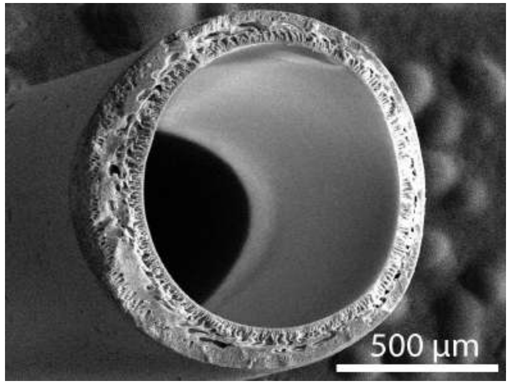
- **Compression, liquefaction, adsorption**
  Thermodynamics, heat and mass transfers



Water treatment

Meeting high purity standards required for electrolysers

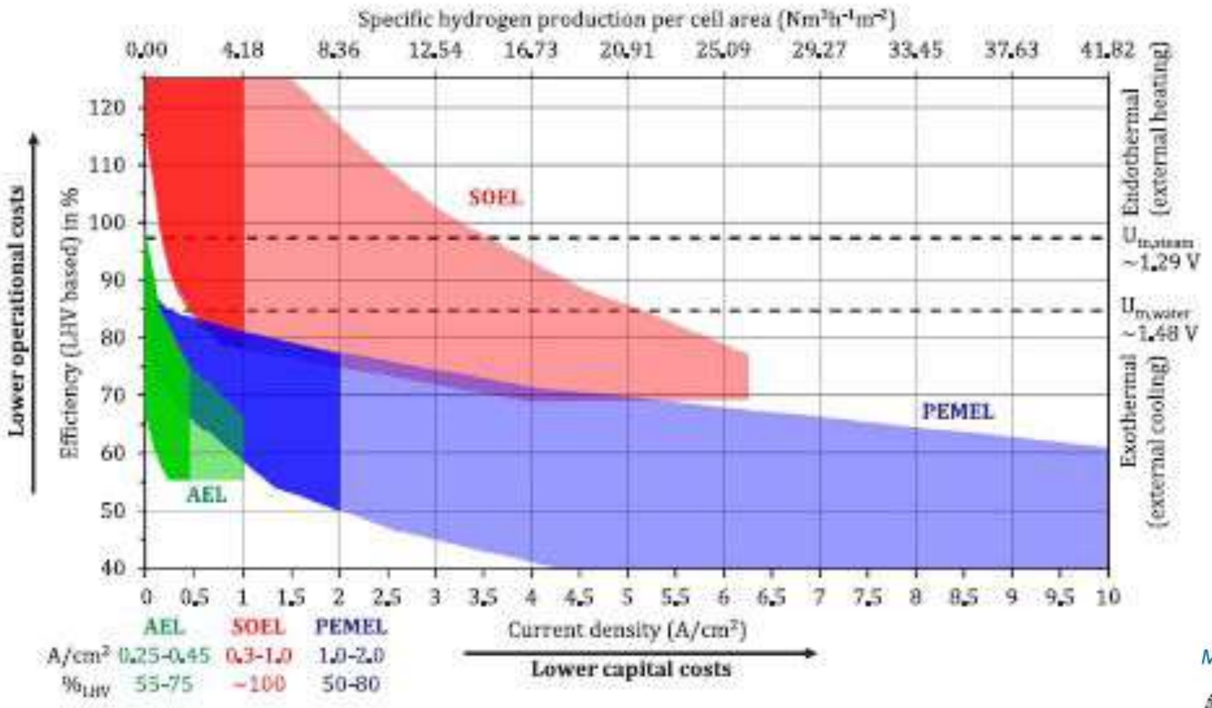
- Pretreatment: removal of suspended solids, biological elements
- **Reverse Osmosis** (RO): ions removal
- Electrodeionisation (EDI): ultra high purification



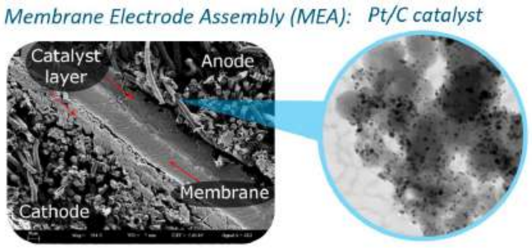
Electrolysers for H_2 production

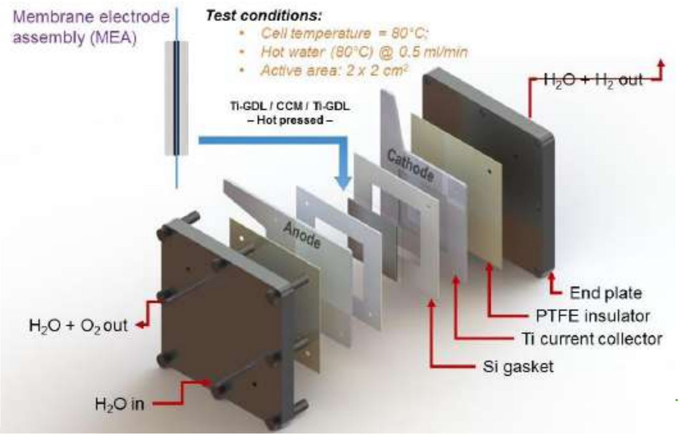
Three main technologies

- Steam water electrolysis (SOEC, PEMWE, MCEC)
- Proton Exchange Membrane (liquid) Water Electrolysis
- Alkaline (liquid) Water Electrolysis



Electrolyzer assembly

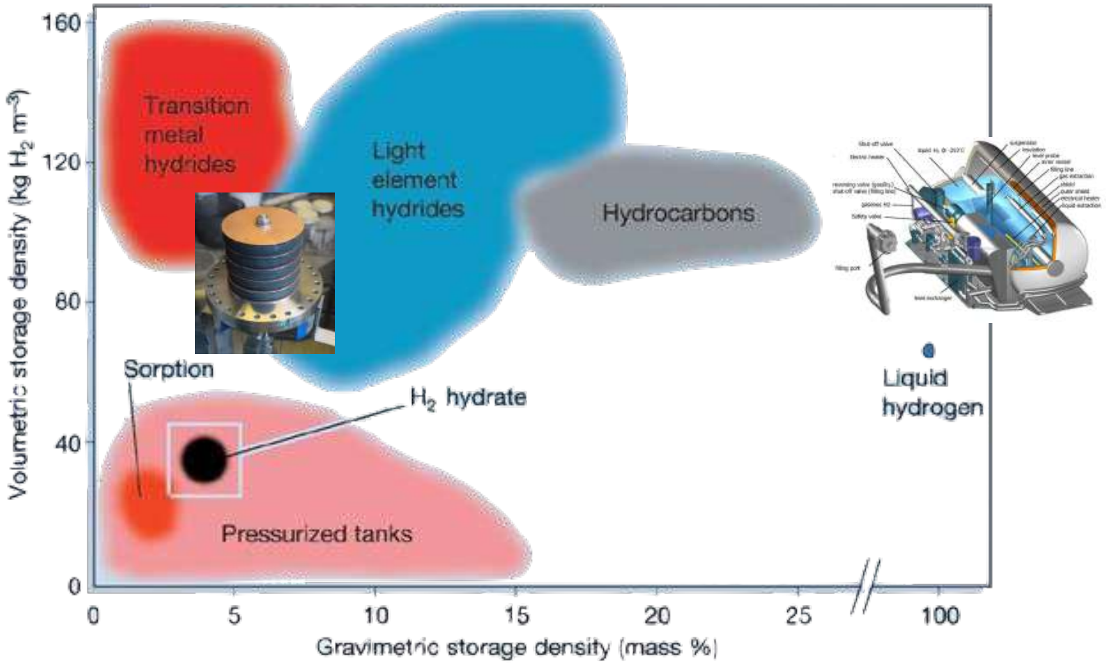


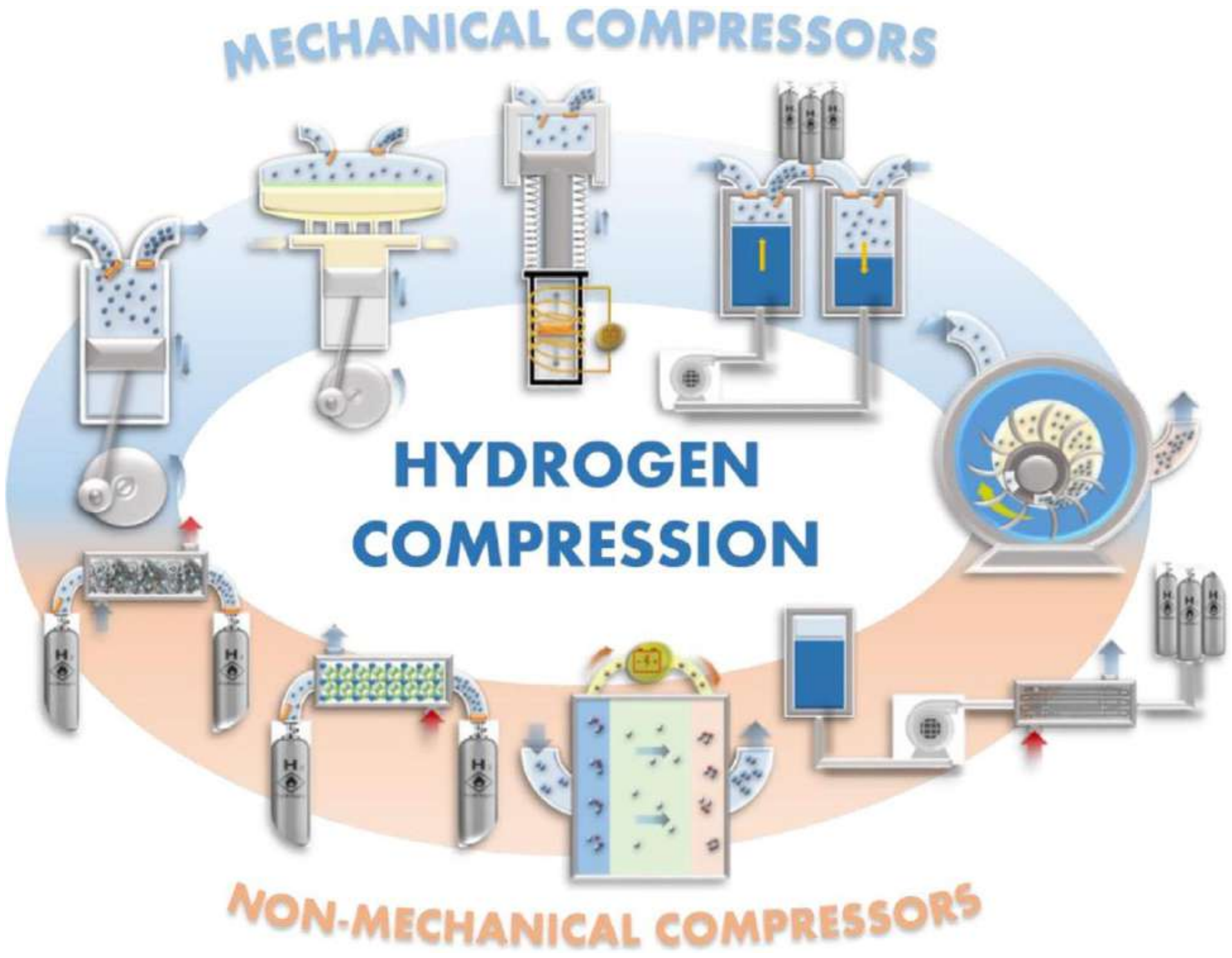


H_2 Storage

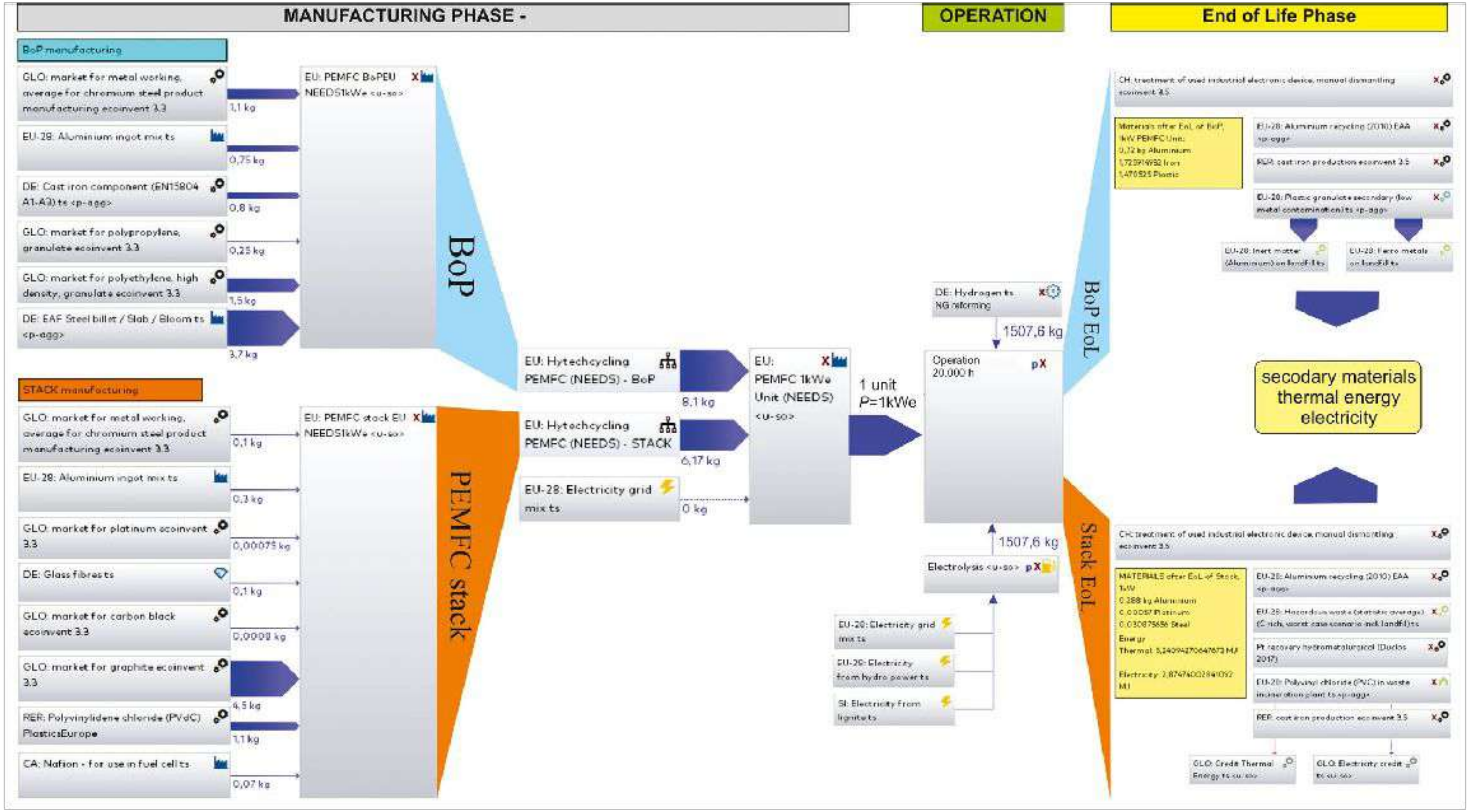
Several approaches

- **Compressed gas**
- Cryogenics storage in a liquid state
- Ab/adsorption in solids
- Liquids and hydrates as H_2 carrier (ammonia, methanol, formic acid)





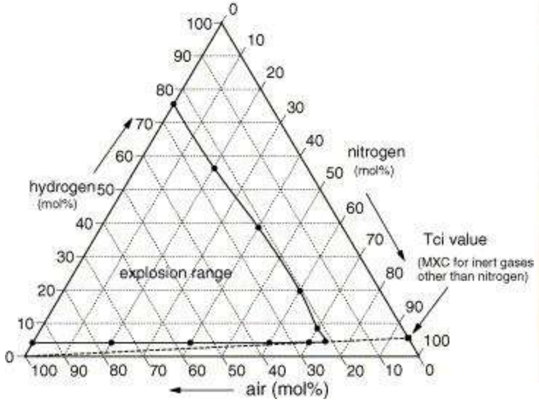
Life cycle considerations

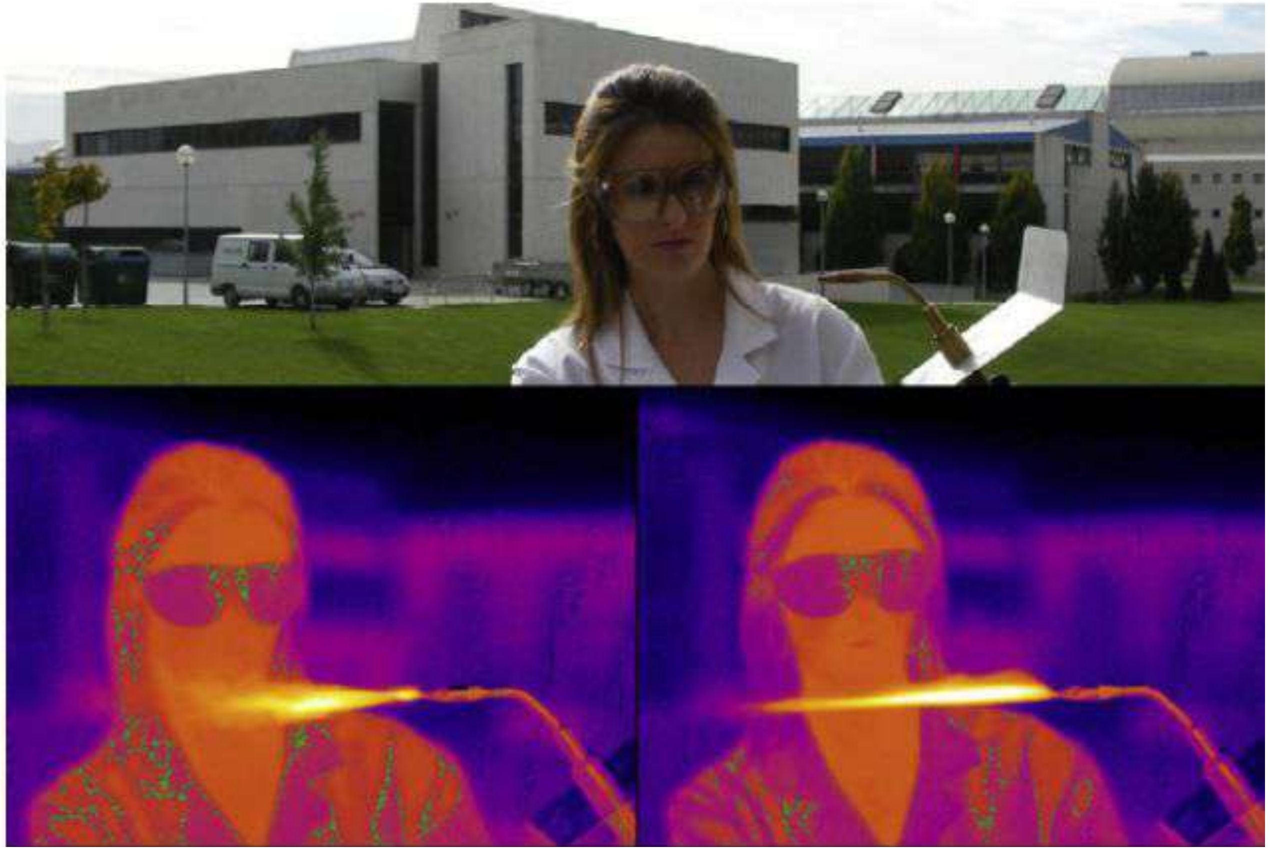


Safety rules summary

- Electrical hazard
- High pressure hazard
- Cryogenic hazard
- Fire and explosion hazard

Uno-X station in Sandvika, Norway June 2019





Course organization and outcomes

12h Practical:

- **Water filtration** with reverse osmosis
- **H_2 production** with a commercial electrolyser
- **Gas compression**

10h Lectures + exercises

- Knowing the theoretical basis related to model the H_2 production through electrolysis
- Able to describe and use the **equipment for water purification**
- Able to describe and use the **equipment for H_2 synthesis**
- Able to describe some approaches for H_2 storage and use the equipment related to the compressed gas approach
- Able to respect the safety rules related to the usage of H_2
- Having some knowledge of the life cycle analysis related to the equipment needed for the green H_2 production

Module 5 – Usage

Con

7.7 PROJECT RESULT – MODULE 5 – USAGES

Result Title	**Module 5: Usage**
Result Leading Organisation	IU1/UGA
Result Participating Organisations	IU1/UGA, UCLL, PANKO, XABEC, TENERRDIS

Result Description (including: needs analysis, target groups, elements of innovation, expected impact and transferability potential)

This module will aim to better understand and illustrate the new uses of renewable energies and hydrogen as a renewable energy vector. Technological progress and the need for storage are giving rise to new uses and new techniques used in an innovative way by companies or start-ups that participate in the development of renewable energy and the decrease of greenhouse gas emissions.

The aim of this module will be to illustrate the multiple uses of the energy mix and to think about the multiple potentialities offered by technological progress thanks to practical cases implemented by leading companies. These case studies will make it possible to link theory and practice around concrete cases and will enable students to project themselves onto cases they might encounter in their future jobs as technicians.

The uses of photovoltaic and wind energy are multiple and interconnected:

- Photovoltaic and wind energy are mainly stored into batteries today, whose energy can be stored into batteries for later use in mobility usage, BIPV, etc.

- Another example concerns their valorisation into hydrogen, considering that it is produced from renewable electricity, numerous uses can be planned. Mobility is a direct expected use of hydrogen for instance in cars (for instance produced by Symbio), in trucks (for instance produced by Volvo or Hyundai Motors) or in trains (for instance produced by Alstom). This mobility sector is however just a part of the hydrogen usage. The numerous uses of hydrogen are strongly related to the intermittency of renewable electricity produced form wind turbines and photovoltaics. A way to store overproduction of electricity converted into hydrogen is the so-called power to gas strategy.

The module should help understanding the multiple conversion of energy under various form envisioned to balance the lack of flexibility of wind turbine and photovoltaics electricity. The understanding of this mechanism is an important output of this module. It is essential that power to gas strategies are developed to promote renewable energy.

This module will give a description of various industrial cases illustrating on the one hand the usage of renewable energies and hydrogen as a renewable energy vector and the relevance of the application to decrease in overall greenhouse gas emissions. The presentation of these situations will further give the opportunity to illustrate the importance of cogeneration and coupling between electricity, gas and heat networks.

A strong demand of technician is expected not only for mobility usages but also within industry which are strong producer of carbon dioxide. It is thus essential that the complex loop related to power to gas strategies is presented to these future

Content

I) Final usage in the global value chain

- Energy supply
- Electricity/gas coupling
- Final usage

II) Electricity and heat production from gas

- Fuel cell
- Gas turbine and heat engine

III) Example of transition

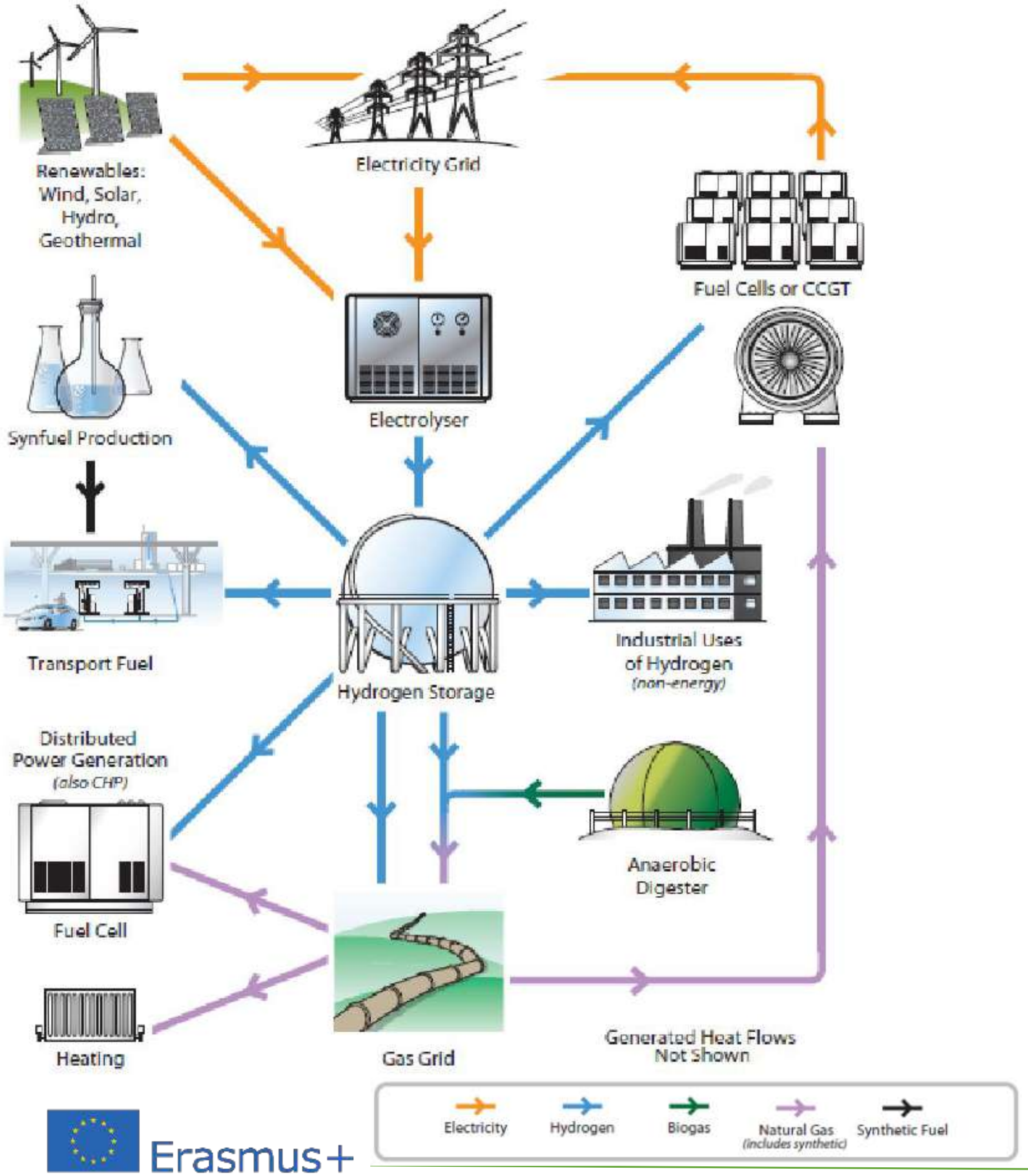
- Transport
- Residential
- Industry

IV) Opportunities/constraints in the future energy mix

- CH_4/H_2, a coupled-green-gas strategy
- Decarbonated electricity supply : strengths and weaknesses
- **Need of a global decrease of energy consumption**

V) Exploitation and maintenance: case studies

Final usage in the global value chain



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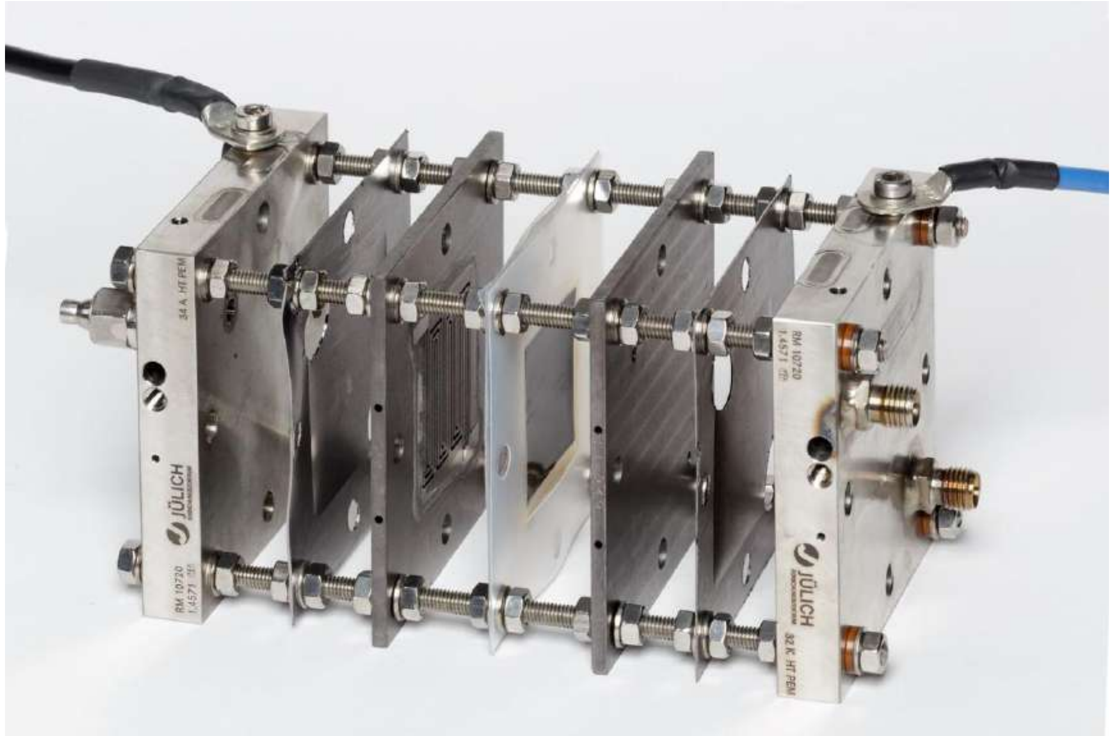
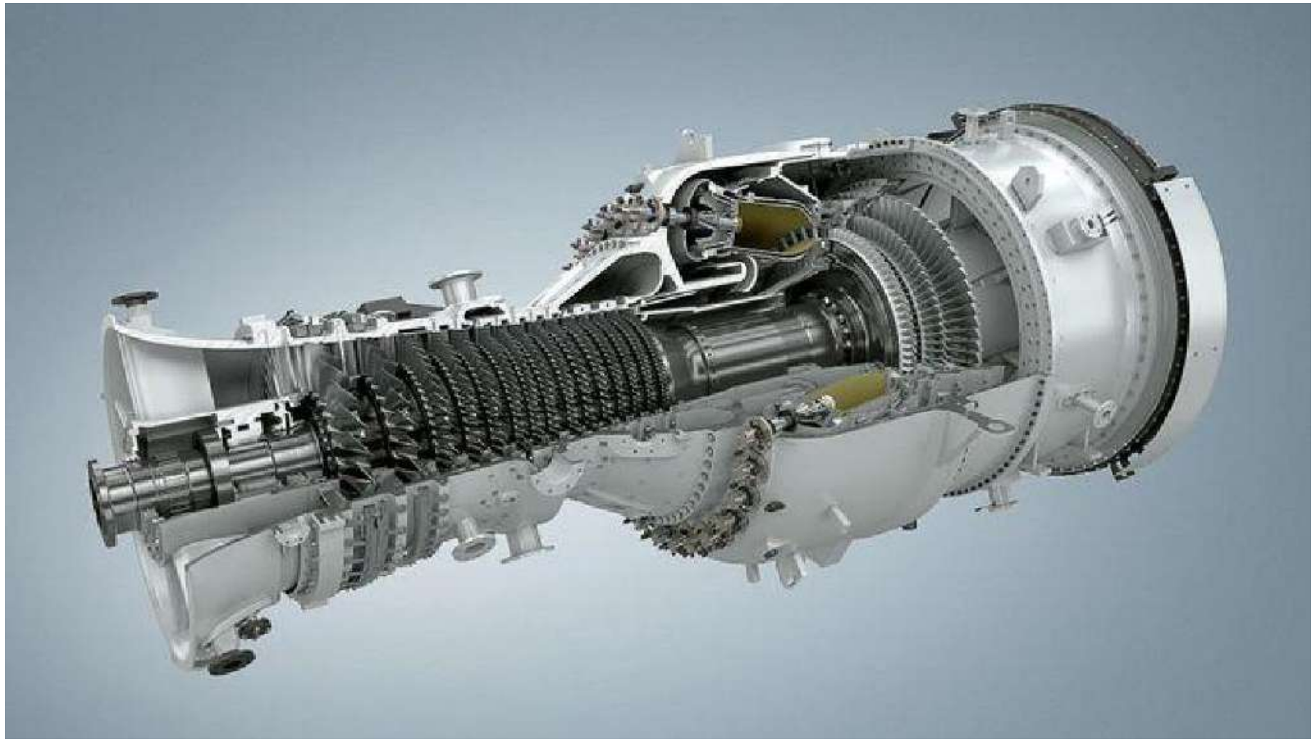
Electricity and heat cogeneration from gas

- **Fuel cell**

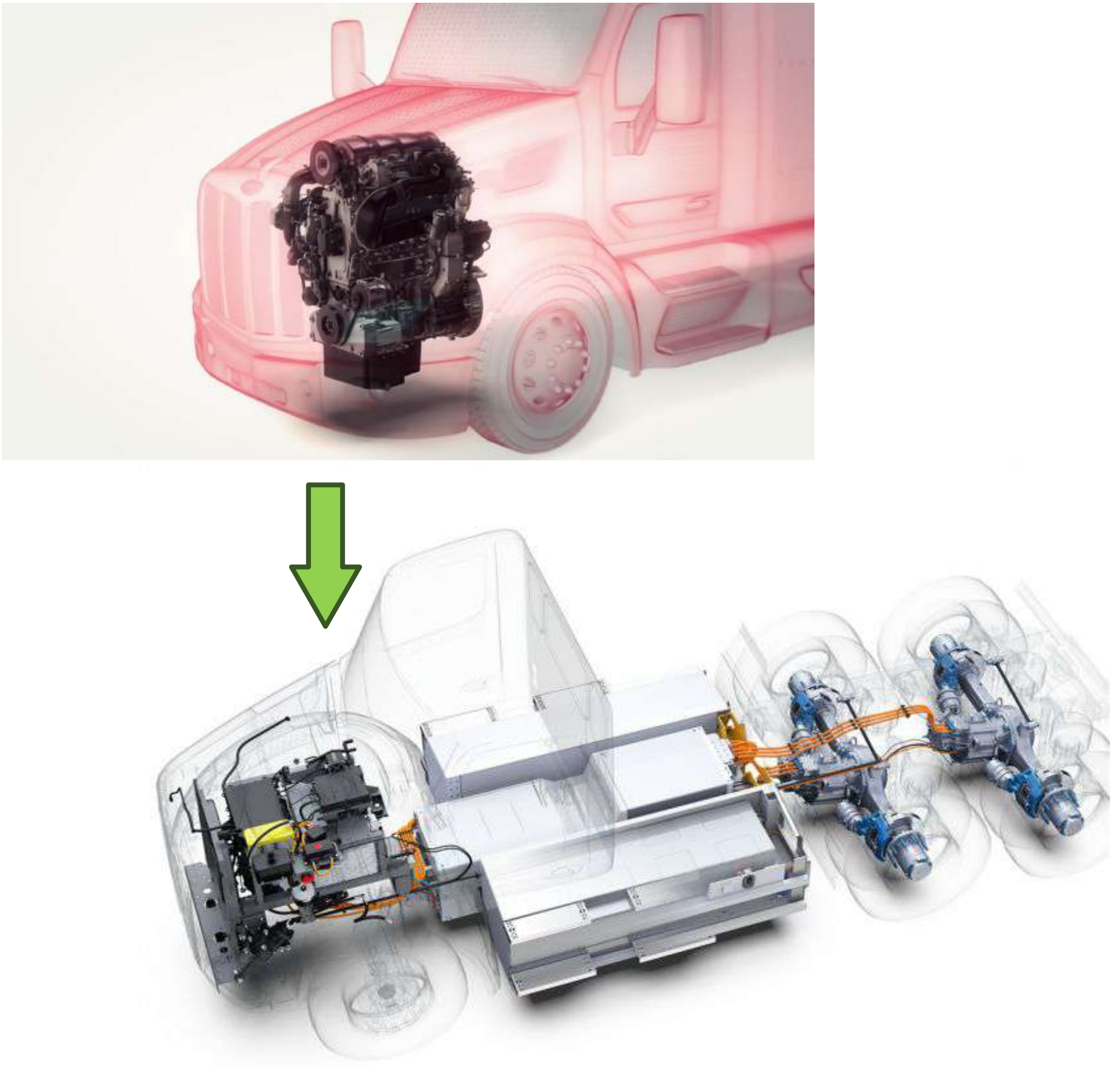
- **Gas turbine and heat engine**
  coupling methane and hydrogen





Examples of transition

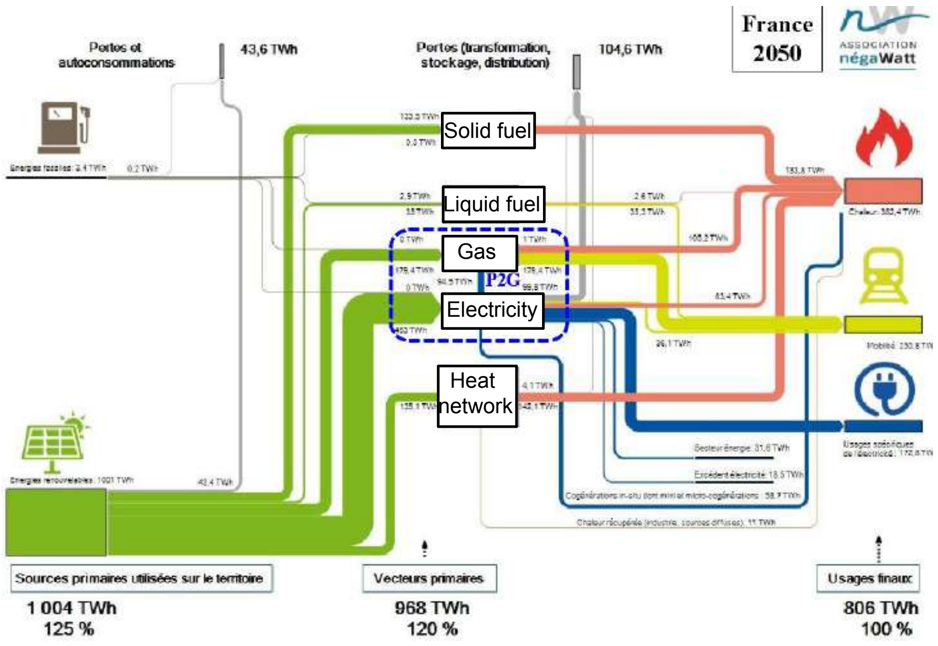
- **Transport**
  From oil to decarbonated sources
- **Residential**
  From top-down to local management
- **Industry**
  From fossil fuel to decarbonated sources

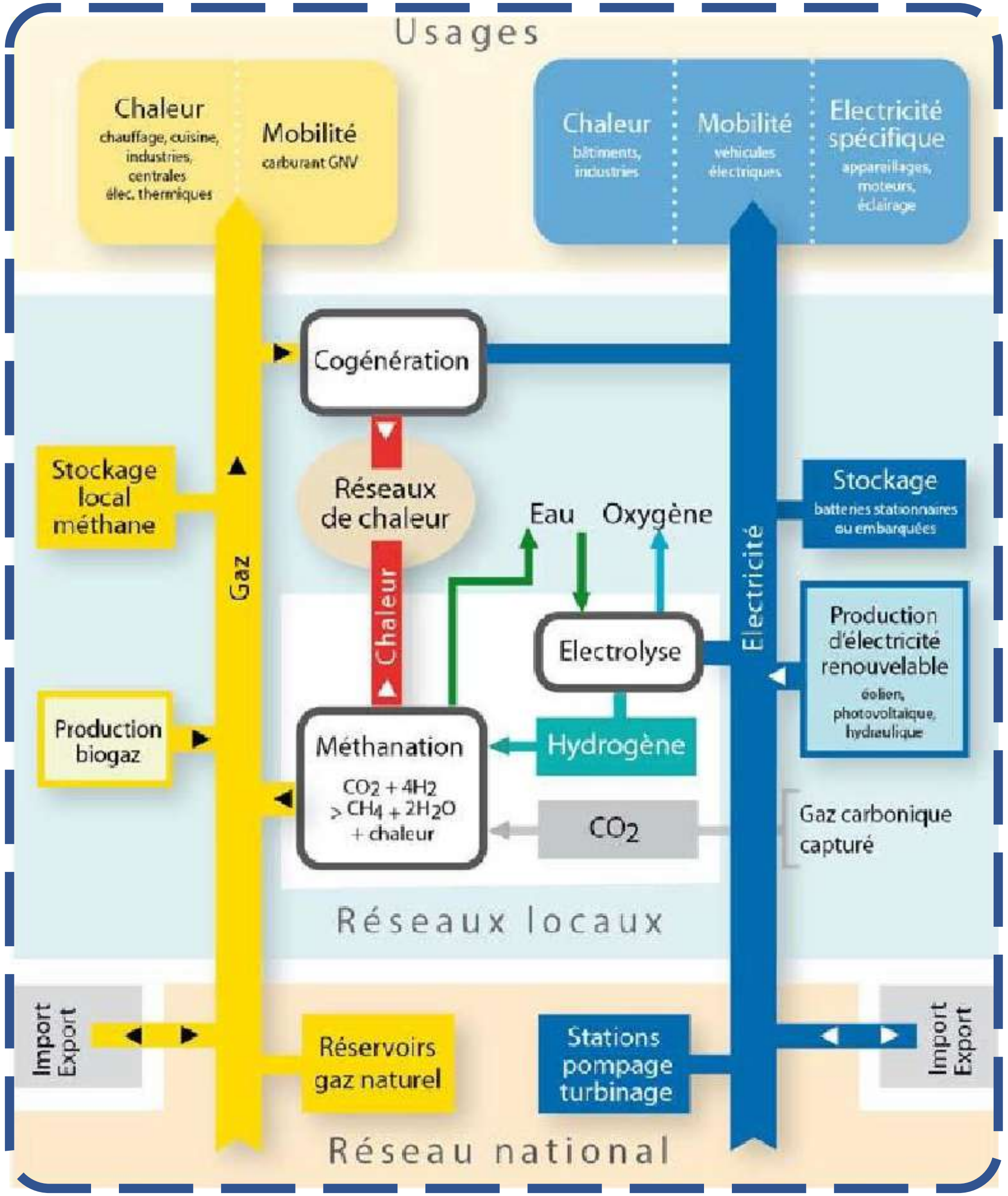


→ **Transition in required competences**

Opportunities/constraints in the future energy mix

- CH_4/H_2, a coupled-green-gas strategy
- Decarbonated electricity supply: strengths and weaknesses
- **Need of a global decrease of energy consumption**





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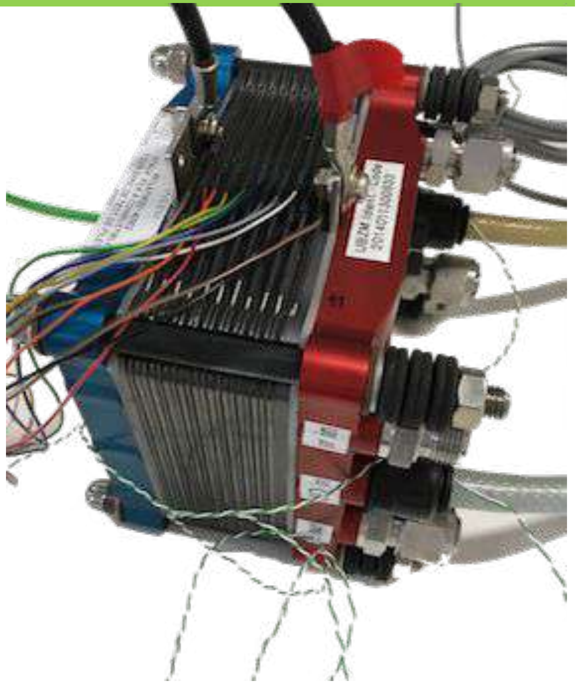
Exploitation and maintenance: case studies

Electricity Production

Storage

Usage

Course organisation and outcomes



8h Practicals :

- Discovering a **global energy chain** based on hydrogen (photovoltaic, electrolysis to produce hydrogen, electricity production in a fuel cell)
- Gas and water handling in a **fuel cell** for electricity and heat **cogeneration**

10h Lectures + exercises

- Able to describe the **upcoming global energy mix**
- Able to explain the main **constraints associated to the future usage** of energy
- Able to describe the **technologies** for electricity and heat cogeneration
- Discovering the classical **maintenance operations** of the main equipment in the energy value chain